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HYPOTHETICAL CASE STUDIES OF OPERATIONAL CHANGES TO REDUCE NOIS--ETC(U)
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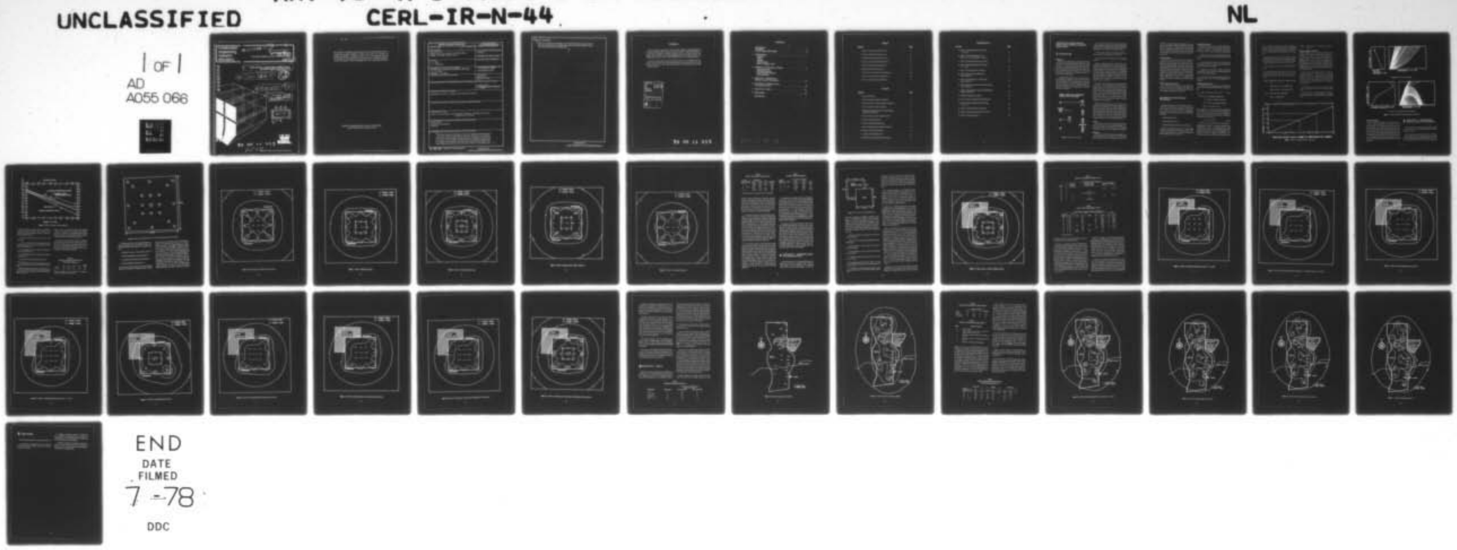

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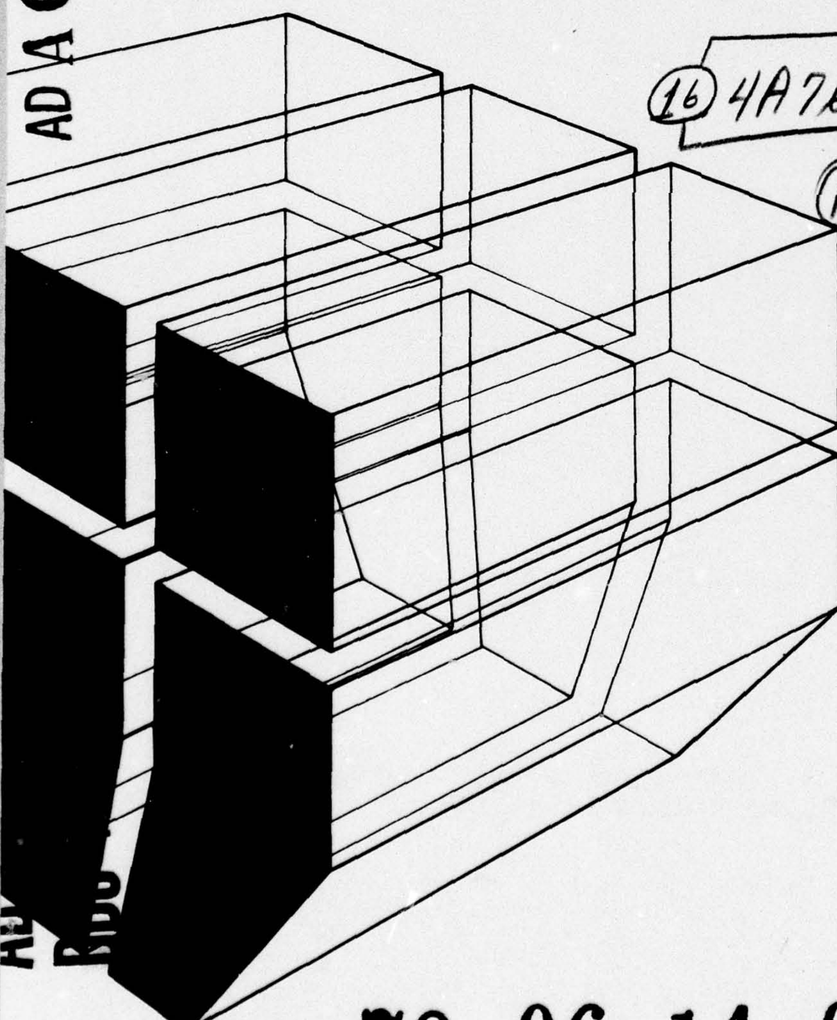

by
Richard R. J. Goff
Violetta V. I. Pawlowska

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This report describes the effectiveness of various noise mitigation techniques as applied to blast noise, the Army's most significant noise source. The main thrust of the analysis was aimed at operational changes, including relocation, rescheduling, and firing during more optimal weather conditions. Three hypothetical case studies were investigated, and each technique was quantitatively evaluated. It was found that the three types of operational changes studied did prove more or less effective. However, these mitigation tech- →

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niques are site-specific, and the decision to use them should be based on how they will affect the base mission, their cost-effectiveness, their noise reduction abilities in terms of decibels, and their benefits to the individual site.

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FOREWORD

This research was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A76270A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task 03, "Pollution Control Technology"; Work Unit 004, "Noise Impact Mitigation Procedures for Army Facilities." The QCR number is 1.03.011. Mr. F. P. Beck, DAEN-MCE-P, is the OCE technical monitor.

The work was performed by the Acoustics Team (ENA) of the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. K. Jain is Chief of EN. COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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HYPOTHETICAL CASE STUDIES OF OPERATIONAL CHANGES TO REDUCE NOISE LEVELS

1 INTRODUCTION

Background

Noise is now recognized as a major pollutant which intrudes on man and his environment. Since the normal operations of Army facilities create noise, the facility has also become aware of this problem. An Army facility attracts people who build homes near the base, but later complain about the noise and may file legal damage suits. Consequently, some bases have had to reduce their training programs.

To alleviate this problem, the U. S. Army Construction Engineering Research Laboratory (CERL) is developing a methodology to predict, assess, and—perhaps most importantly—to reduce noise impact caused by the normal operations of Army facilities. These noise reduction techniques can be classified into three basic categories (see Figure 1).

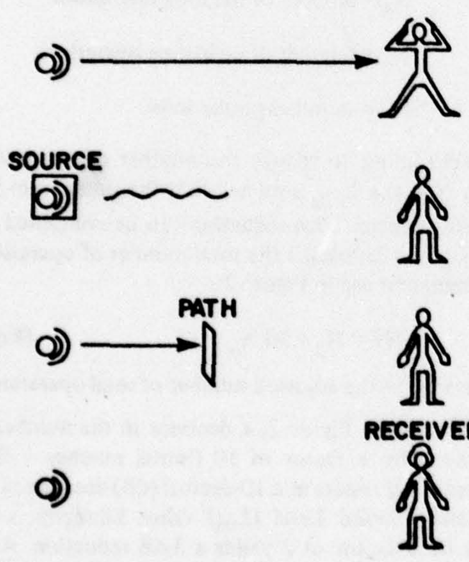


Figure 1. Source–path–receiver.

1. Noise can be quieted at the source through either a design modification which reduces the actual level of emitted noise, or through an operational change, which reduces the level of noise perceived by the receiver.

2. Noise can be reduced by modifying the path over which it travels from the source to the receiver.

3. Noise impact can be mitigated by protecting the receiver.

CERL is conducting research to determine the effectiveness, feasibility, and cost of each of these techniques; and all of these factors must be evaluated and weighed against each other before the best technique(s) for a given situation can be determined. For example, the most effective technique in terms of actual decibel reduction should not necessarily be applied if it is also the most expensive. Similarly, if the most cost- and decibel-effective technique interferes with the base mission, it may be rejected.

Prediction methodology produces equal noise contours, which, when superimposed on land-use maps, identify areas of noise impact. Impact can then be quantified in terms of area or people exposed to a particular noise level. By applying various mitigation techniques to this prediction methodology and comparing the resulting impact with the initial impact, a technique's effectiveness can be readily evaluated. Unfortunately, work in the more abstract areas of cost and feasibility is not as advanced.

Operational changes appear to be the most cost-effective and easily implemented noise mitigation techniques at present. While Army facilities contain many noise sources (blast, helicopter, traffic, fixed-wing aircraft, construction, power plants, etc.), blast noise is the most significant noise source. The area impacted by these operations can often exceed hundreds of square miles. Consequently, this is the easiest source on which to demonstrate the value of operational techniques.

Purpose

The purpose of this report is to illustrate the application and effectiveness of operational changes in reducing noise impact. The application of these changes will be shown via a series of hypothetical case studies.

Approach

Equal noise contours were plotted, using CERL computer techniques for blast operations at a hypothetical Army facility. Impact was quantified in terms of area

within the various C-weighted day-night level ($L_{C_{dn}}$) contours. Then three operational techniques were applied to the activity: (1) rescheduling, (2) relocating, and (3) conducting operations under more optimal weather conditions. The effectiveness of each technique was evaluated in terms of reduction in size of the impacted area.

Outline of Report

To demonstrate and evaluate the various operational technqiues for reducing noise, this report has been organized as follows. Chapter 2 discusses the basic concepts of operational changes. In Chapter 3, these operational techniques are used in a first case study to reduce the overall land area exposed to high noise levels. Chapter 4 shows the application of these techniques in a second case study in which impact was reduced in a specific noise-sensitive area. Chapter 5 ties together these concepts in a case study of a theoretical Army facility, and Chapter 6 provides the conclusions of the research.

Mode of Technology Transfer

This report will be distributed to the facilities by means of TAG (Task of the Adjutant General) letter. It is the first in a series of bulletins designed to assist Army facilities in reducing noise impacts.

2 SUMMARY OF OPERATIONAL CHANGES

Operational changes are those changes made to a noise source which reduce the level of noise perceived by a receiver, but not the actual level emitted by a source. In the case of armor, artillery, or demolition operations, operational changes consist of the following techniques:

1. Relocating the source

2. Rescheduling operations

3. Operating during optimal weather conditions.

The 8-in. (204-mm) gun and the 5-lb (2.3-kg) charge of TNT will produce the same noise level with or without these changes; however, the changes will reduce the level of noise perceived by a receiver.

Relocating the Source

Relocating is the selection of a better location for a noise source in relation to noise-sensitive areas. Besides the obvious solution of locating a source as far as possible from a receiver, there are several other approaches:

1. Dispersing the activity will increase the amount of area affected, but will decrease the severity of the effects.

2. Concentrating the activity into a compact area will decrease the amount of land affected, but will increase the severity of the impact.

3. Activities can be located at night in areas used only during the day, such as areas containing schools, churches, and office buildings.

4. Activities can be located according to season, e.g., during the winter next to outdoor amphitheaters or stadiums.

Rescheduling Operations

The equation for calculating $L_{C_{dn}}$ from intermittent sources can be used to explain the concept of rescheduling.

$$L_{C_{dn}} = SEL + 10 \log_{10} (N_d + 10N_n) - 49.4 \qquad \text{(Eq 1)}$$

where $L_{C_{dn}}$ = C-weighted day-night level

N_d = number of daytime operations

N_n = number of nighttime operations

SEL = sound exposure level.

By rescheduling to reduce the number of operations (N_d or N_n), the $L_{C_{dn}}$ level and thus the subsequent impact are reduced. This reduction can be computed by using Eq 2 to determine the total number of operations for subsequent use in Figure 2.

$$NT = N_d + 10\,N_n \qquad \text{(Eq 2)}$$

where NT = the adjusted number of total operations.

As illustrated in Figure 2, a decrease in the number of operations by a factor of 10 (initial number ÷ final number = 10) results in a 10-decibel (dB) decrease in the Equivalent Sound Level (L_{eq}) value. Similarly, a decrease by a factor of 2 yields a 3-dB reduction. A reduction factor less than 1 implies an increase in opera-

tions; a negative decrease is also an increase. The L_{eq} measure is used as an alternate means of calculating $L_{C_{dn}}$, therefore decreases/increases in $L_{C_{dn}}$ are reflected in the corresponding decreases/increases in the L_{eq} value.

Because people are more sensitive to nighttime noise (as indicated by the 10-dB penalty imposed on nighttime operations [Eqs 1 and 2]), scheduling operations to reduce N_n will produce an even lower $L_{C_{dn}}$ level.

The following is an example of rescheduling operations.

A base has 100 daily blast operations—90 at night and 10 during the day. What is the $L_{C_{dn}}$ reduction if 80 night operations are rescheduled as daytime operations?

Step 1. Determine total number of operations using Eq 2

Original number = 10 + 90(10) = 910

Reduced number = 90 + 10(10) = 190

Step 2. Determine factor of decrease

factor = 910/190 = 4.8

Step 3. From Figure 2, a reduction of 6.8 dB is found.

Optimizing Weather Conditions

Large-amplitude noise from blast and artillery can be heard from long distances and is significantly affected by the weather. Wind and temperature gradients can vary the speed of sound in different directions and at different altitudes. As a result, the atmosphere can sometimes act as a lens, redirecting waves traveling away from the ground and focusing them at distant points (Figure 3). This focus creates noise levels that can be 30 dB higher than those under more favorable weather conditions (Figure 4).

Consequently, noise impact can be reduced by scheduling operations in accordance with specific weather conditions, i.e., having limited firing during focusing conditions and unlimited firing during conditions which cause large attenuation, such as when the sound velocity decreases with altitude, as in a temperature inversion.[1,2]

[1] P. D. Schomer, *Predicting Community Response to Blast Noise*, Technical Report E-17/ADA773690 (CERL, December 1973).

[2] P. D. Schomer, R. J. Goff, and L. Little, *The Statistics of Amplitude and Spectrum of Blast Propagated in the Atmosphere*, Technical Report N-13/ADA033475 (CERL, November 1976).

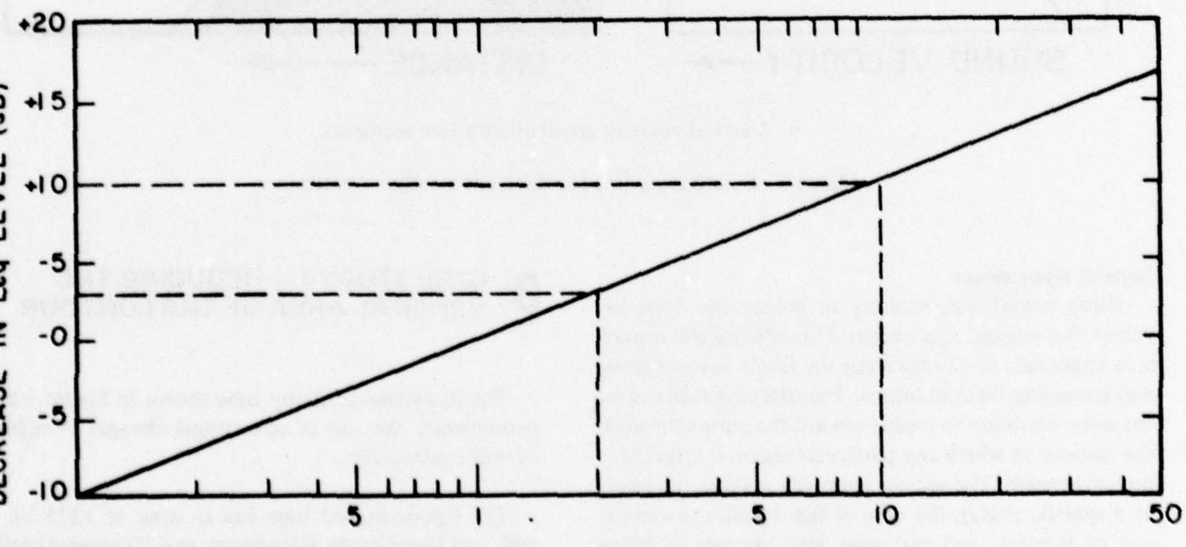
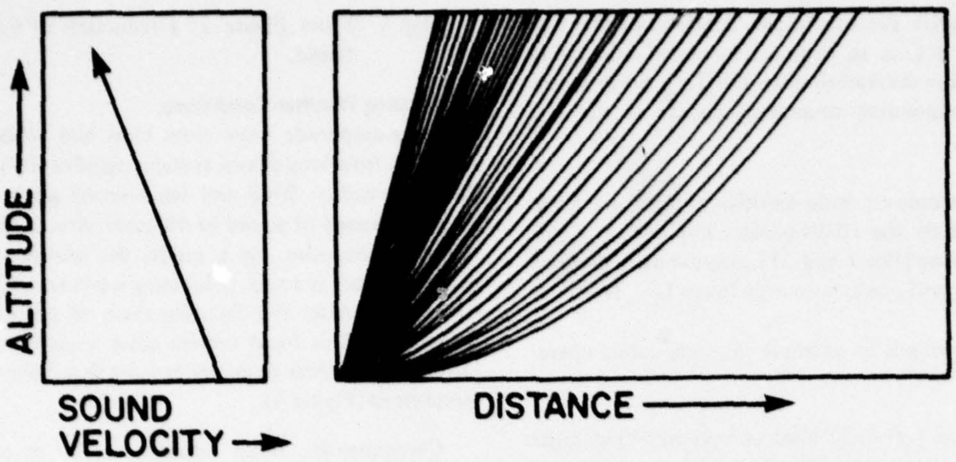
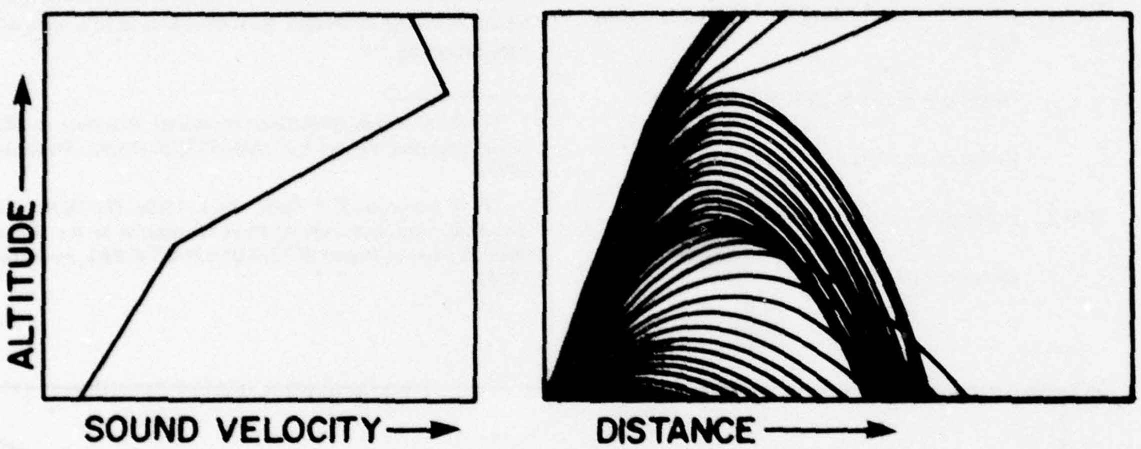


Figure 2. Effect of reducing number of operations.



a. Negative vertical velocity gradient.



b. Vertical velocity gradient with two segments.

Figure 3. Sound ray paths for different weather conditions.

General Approaches

Using operational changes to reduce the noise involves two general approaches: (1) reducing the overall area impacted, or (2) reducing the levels in some areas and increasing them in others. The first approach causes the noise contours to recede toward the noise source(s); the manner in which any particular region is affected is not of interest. The second approach reduces the levels at a specific site(s); the area of the overall contours is not of interest, and the noise may increase in other areas. The following chapters illustrate these two approaches.

3 CASE STUDY I – REDUCING THE GENERAL AREA OF THE CONTOUR

The hypothetical Army base shown in Figure 5 will demonstrate the use of operational changes to reduce overall contour size.

The square-shaped base has an area of 1225 km^2, with one target point at its center, and 20 symmetrically located firing points surrounding the target point. Before quantifying the effects of any noise reduction

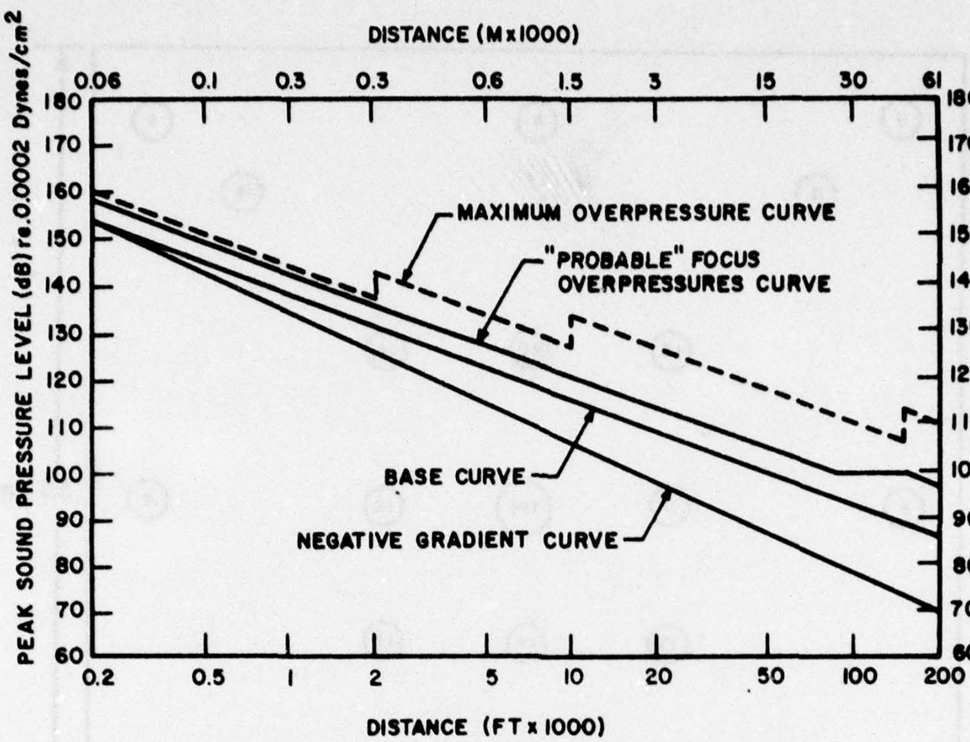


Figure 4. *Effects of weather on blast amplitude.*

technique, baseline conditions must be established. Consequently, the following initial conditions were placed in the CERL computer program[3] and used to generate baseline contours.

1. Thirty rounds are fired every 24 hours at each firing point

2. Fifteen rounds are fired during the daytime (0700-2000 hours) and 15 rounds are fired during the night-time (2200-0700 hours)

3. The equivalent of 5 lb (2.3 kg) of C4 explosive is used to propel each round

4. The equivalent of 5 lb (2.3 kg) of C4 is contained in each warhead

5. There are average temperature inversions*

[3] P. D. Schomer, *Predicting Community Response to Blast Noise*, Technical Report E-17/ADA773690 (CERL, December 1973).

*This assumes that inversions occur at ground level, 1 to 500 m, and 1 to 3000 m at 74.2 percent, 8.6 percent, and 18.6 percent of the time, respectively, at 2400 hours Greenwich Mean Time (GMT).

Figure 6 shows the resulting contours. By applying operational techniques to these initial conditions, generating new contours, and comparing them with the baseline contours, the effectiveness of each technique can be quantified in terms of decibel reduction.

As the first step, the baseline contours in Figure 6 are quantified in Table 1. Here it is shown that 259.1 km^2 lies in a region with an $L_{C_{dn}}$ higher than 75 dB; an area of 250.4 km^2 falls between $L_{C_{dn}}$ 70 and 75, etc. This table could have been subdivided further to indicate land on-post versus land off-post.

Table 1
Impact From Initial Conditions (Case I)
(Noise Level in dB $L_{C_{dn}}$)

$L_{C_{dn}}$	<65	65-70	70-75	>75	Total* Area
Area in km^2	58.1	658.4	250.4	259.1	1225

*Table only considers 1225 km^2 in Figure 6. No attempt is made to extrapolate contours off figure.

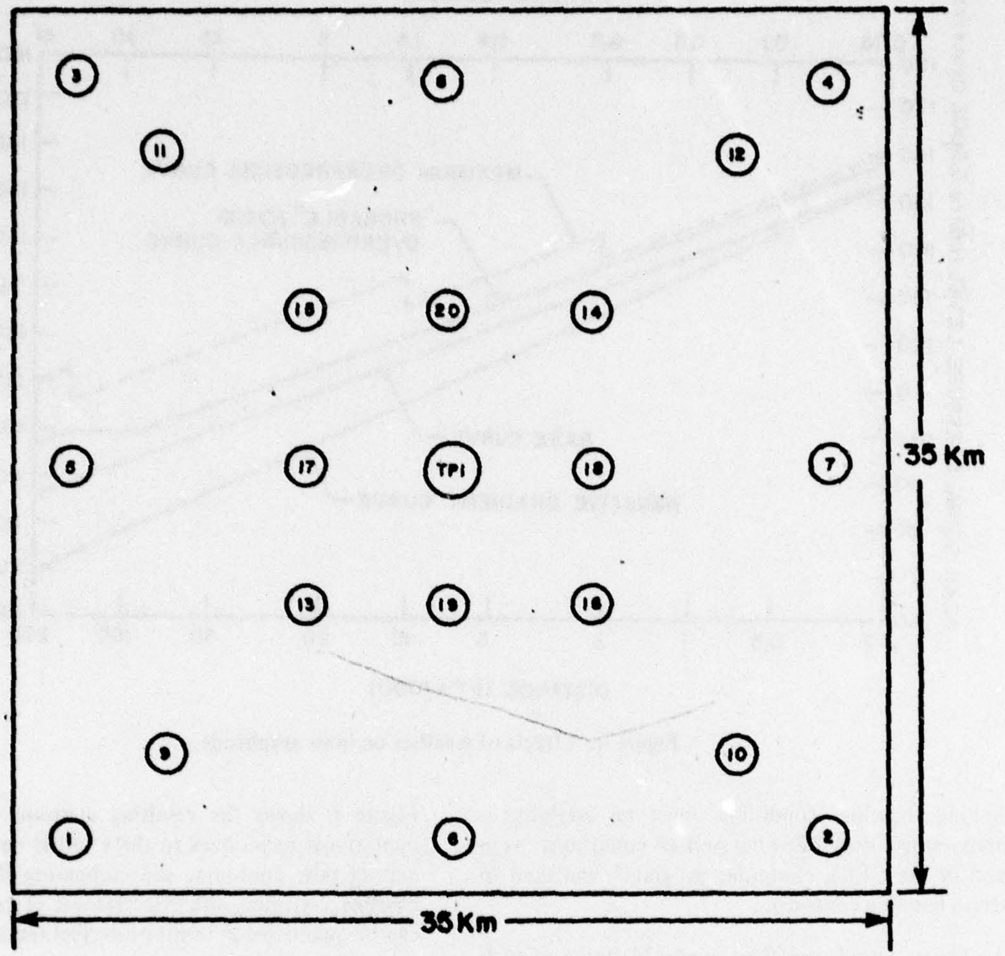


Figure 5. Base with one target point and 20 symmetrically distributed firing points.

To demonstrate the use of operational changes in reducing the general area of the baseline contours, the following variations were applied to the initial conditions:

1. Halving the number of daily operations (Figure 7)
2. Eliminating nighttime operations (Figure 8)
3. Using optimum weather conditions (Figure 9)
4. Relocating firing points (Figure 10).

The contours for these variations have been overlaid on Figure 6 for purposes of comparison. Table 2 summarizes the results by comparing the area of land encompassed by the different $L_{C_{dn}}$ contours. As a further comparison, Table 3 was compiled to list the cumulative area. For example, under baseline conditions in Figure 6, 509.5 km^2 of land experienced levels of $L_{C_{dn}}$ 70 or more. Similarly, 1167.9 km^2 of land experienced levels of $L_{C_{dn}}$ 65 or more, etc. The first change (halving both daytime and nighttime operations) is shown in Figure 7. From Figure 2, if the number of operations is halved, the $L_{C_{dn}}$ value decreases by 3 dB. From a land area standpoint, the reduction is quite significant. The land experiencing noise levels in excess of $L_{C_{dn}}$ 75 is decreased from 259.1 to 174.1 km^2, while land experiencing noise levels in excess of $L_{C_{dn}}$ 65 is decreased almost 30 percent, from 1167.9 to 727.8 km^2. The de-

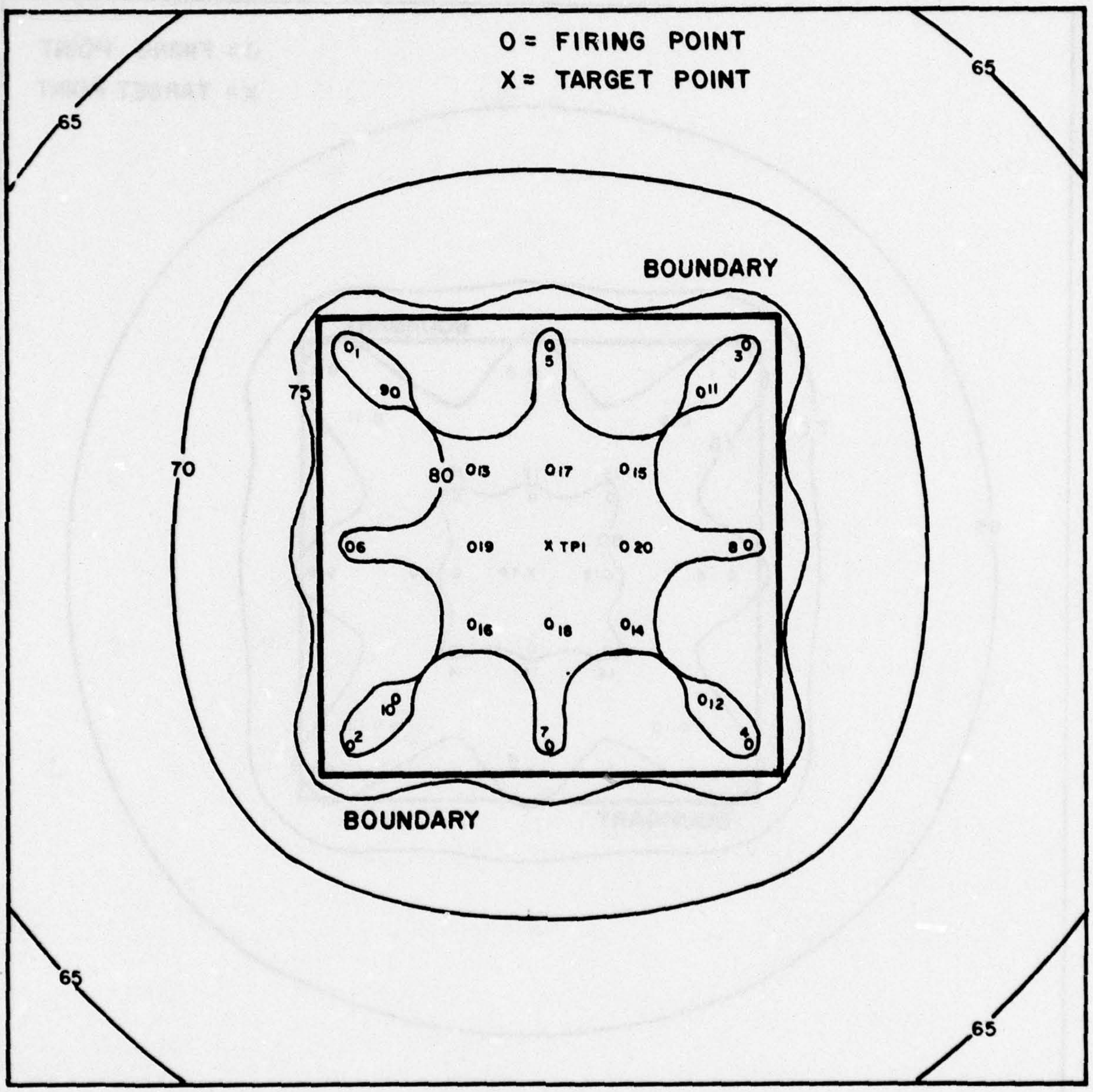


Figure 6. Noise contours for initial conditions (Case I).

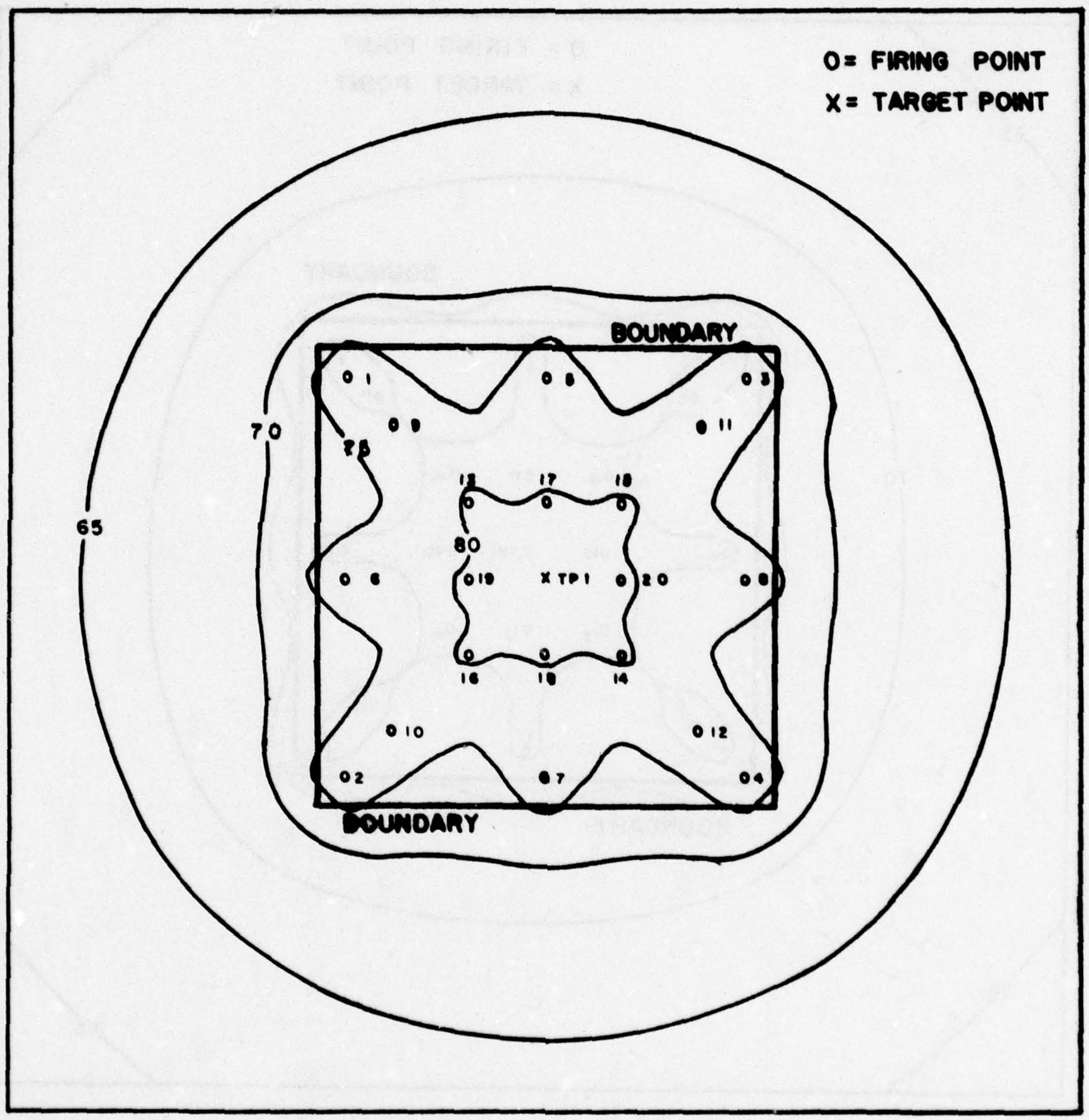


Figure 7. Effects of halving operations.

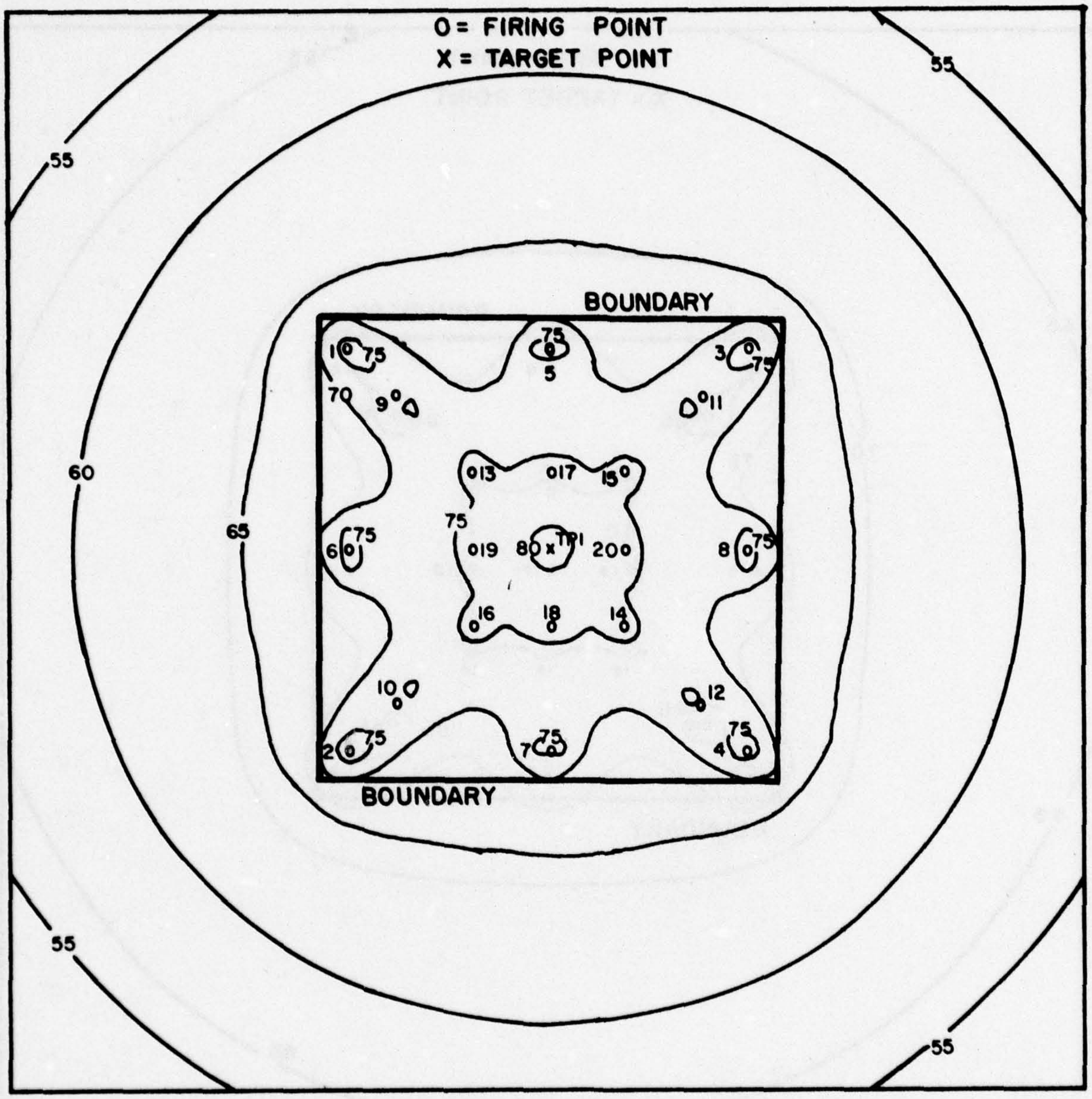


Figure 8. Effects of eliminating night firings.

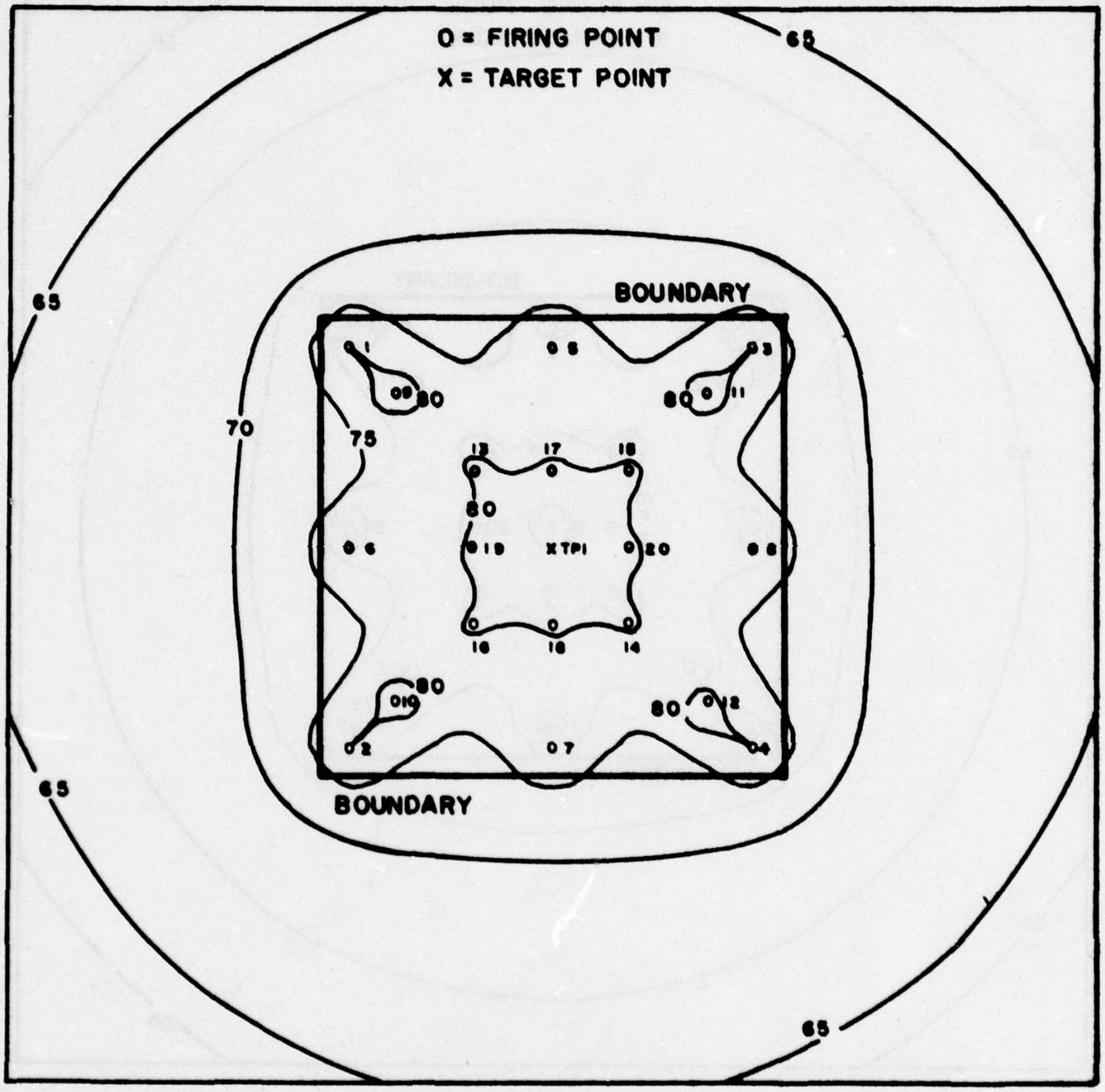


Figure 9. Effects of using optimum weather conditions.

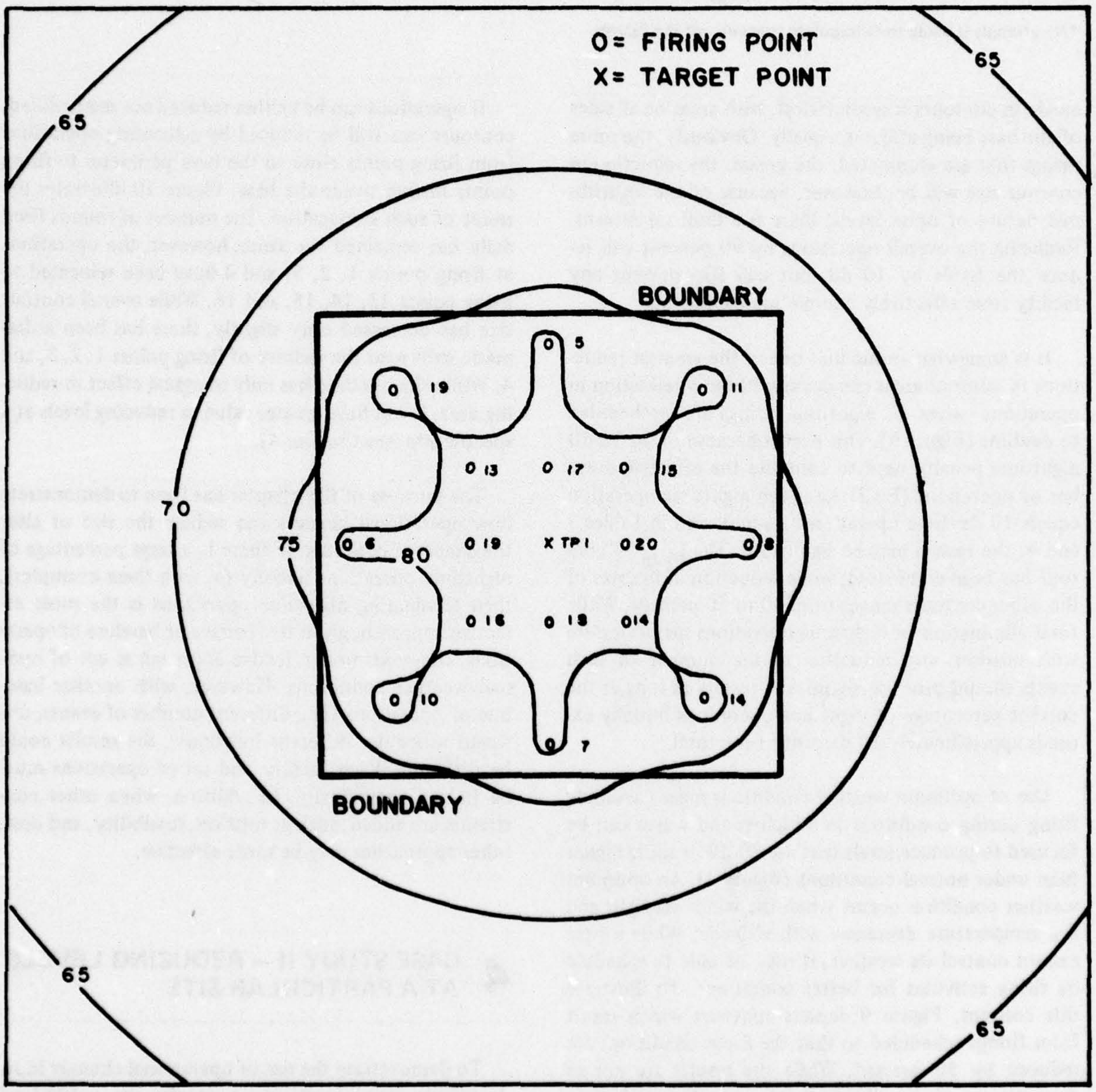


Figure 10. Effects of relocating firing points.

Table 2
Effects of Operational Changes (Case I)

figure \ $L_{C_{dn}}$	Area (km^2) 60-65	65-70	70-75	>75	Total Area
6		658.4*	250.4	259.1	1225
7		394.1	159.6	174.1	1225
8	119.8	467.9	159.1	–	1225
9		637.6*	174.3	200.0	1225
10		700.9*	239.6	222.6	1225

*No attempt is made to extrapolate contours off the figures.

Table 3
Cumulative Land Area Impacted

figure \ $L_{C_{dn}}$	Land Area (km^2) Impacted >60	>65	>70	>75
6		1167.9	509.5	259.1
7		727.8	333.7	174.1
8	746.8	622.0	159.1	–
9		1011.9	374.3	200.0
10		1163.1	462.2	222.6

crease in contours is symmetrical, with areas on all sides of the base being affected equally. Obviously, the more firings that are eliminated, the greater the reduction in contour size will be; however, because of the logarithmic nature of noise levels, there is a limit on returns. Reducing the overall operations by 90 percent will reduce the levels by 10 dB, but will also prevent any facility from effectively completing its mission.

It is somewhat ironic that one of the greatest reductions in contour areas can occur without a reduction in operations—when all nighttime firings are rescheduled to daytime (Figure 8). This occurs because of the 10-dB nighttime penalty used to compute the effective number of operations (Eq 2); i.e., each nighttime operation equals 10 daytime operations. As indicated in Tables 3 and 4, the results may be significant. The $L_{C_{dn}}$ 75 contour has been eliminated, while reduction in the size of the other contours ranges from 40 to 50 percent. While total elimination of nighttime operations may interfere with mission, any reduction in the number of such events should produce significant results as long as the current percentage of nighttime operations initially exceeds approximately 10 percent of the total.

Use of optimum weather conditions means avoiding firing during conditions in which sound waves can be focused to produce levels that are 30 dB or more higher than under normal conditions (Figure 4). An optimum weather condition occurs when the winds are light and the temperature decreases with altitude. While a base cannot control its weather, it may be able to schedule its firing activities for better conditions. To illustrate this concept, Figure 9 depicts contours which result from firings scheduled so that the focus conditions are reduced by 50 percent. While the results are not as dramatic as those obtained by reducing nighttime operations, the reduction in impacted land area is still significant.

If operations can be neither reduced nor rescheduled, contours can still be reduced by relocating operations from firing points close to the base perimeter to firing points further inside the base. Figure 10 illustrates the result of such a relocation. The number of rounds fired daily has remained the same; however, the operations at firing points 1, 2, 3, and 4 have been relocated to firing points 13, 14, 15, and 16. While overall contour size has decreased only slightly, there has been a dramatic shift near the vicinity of firing points 1, 2, 3, and 4. While this method has only marginal effect in reducing area, it will have greater value in reducing levels at a specific site (see Chapter 4).

The purpose of this chapter has been to demonstrate how operational changes can reduce the size or alter the shape of contours. If there is a large percentage of nighttime operations initially (as with these examples), then eliminating nighttime operations is the most effective approach, given this particular baseline of operations; the next most effective approach is use of optimal weather conditions. However, with another baseline of operations (i.e., different number of events, different schedule, different locations), the results could be different. Each facility and set of operations must be judged individually. In addition, when other constraints are added, such as mission, feasibility, and cost, other approaches may be more effective.

4 CASE STUDY II – REDUCING LEVELS AT A PARTICULAR SITE

To demonstrate the use of operational changes in reducing the noise levels at a particular site, a 100-km^2 noise-sensitive area was established at the northwest corner of the hypothetical base (Figure 11). The pro-

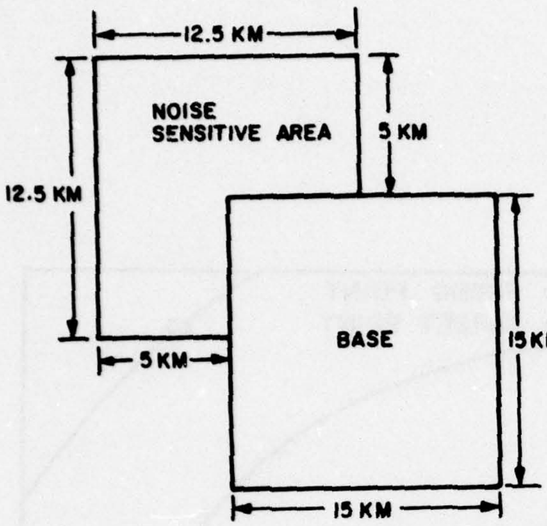


Figure 11. Location of noise-sensitive area.

cedure for evaluating the different techniques is the same as that discussed in Chapter 3. First, a baseline situation was set up by generating contours for an original set of operating conditions; then changes to these conditions were used to generate contours which were used in turn to quantify the effectiveness of the technique. The following initial conditions were applied to the CERL computer program[4] to generate baseline contours:

1. Thirty rounds are fired during each 24-hour day at each firing point

2. All rounds are fired during the nighttime (2200-0700 hours)

3. The equivalent of 5 lb (2.3 kg) of C4 is used to propel each round

4. The equivalent of 5 lb (2.3 kg) of C4 is detonated in each warhead

5. Standard temperature inversion factors are used (74.2, 8.6, 18.7).

The resulting contours shown in Figure 12 reveal that approximately one-third of the noise-sensitive area lies within the $L_{C_{dn}}$ 75 dB contour, while more than 90 percent lies within the $L_{C_{dn}}$ 70 contour. For this particular case study, the objective is to reduce the noise levels in this noise-sensitive region; there will be little concern for the shapes of contours and other land areas impacted as a result of any action taken to achieve this goal.

The operational changes to be considered are variations in rescheduling and relocating. At present, use of optimal weather conditions is applicable only for reducing the general size of contours. In any event, by applying various degrees of operational changes to specific firing points, both the size and shape of the contours in Figure 12 can be altered to reduce the impact on a particular noise-sensitive area.

Tables 4 and 5 summarize each of the actions taken and indicate the corresponding effects on the noise-sensitive area. Table 5 also shows the effects on the general contour area. Note that under the initial conditions, 100, 95, and 31 km^2 of the noise-sensitive area are exposed to $L_{C_{dn}}$ levels of 65, 70, and 75, respectively. The purpose of the following set of actions is to reduce the land area in each of these $L_{C_{dn}}$ noise zones. The results are illustrated in Figures 13 through 21. Again, for comparison, the figures have been overlaid with the initial conditions.

Figure 13 shows the contours that result from eliminating operations at firing points adjacent to the noise-sensitive area—points 1, 5, 6, and 9. The results indicate that the area exposed to $L_{C_{dn}}$ 75 has been nearly eliminated (down to 1 km^2 from 31 km^2), while the area exposed to $L_{C_{dn}}$ 70 has been reduced from 95 to 82 km^2. Although not of primary importance, the general size of the contours has also been reduced. While these results are significant, it should be noted that approximately 20 percent of the firing points (4 out of 20) had to be eliminated to achieve this reduction in impacted area. If such a cutback interferes with mission, similar results can be achieved by using the alternative action of relocating these operations to firing points 4, 7, 8, and 12 (Figure 14). Again, the area exposed to $L_{C_{dn}}$ 75 is almost eliminated (down to 2 km^2 from 31 km^2). However, there is a trade-off; while the area exposed to 70 dB remains the same (down to 93 km^2 from 95 km^2), the total number of operations has not been cut.

Figures 15, 16, and 17 show the results of rescheduling operations from night to day. Because of the 10-dB penalty for night operations (Eq 2) and the results

[4] P. D. Schomer, *Predicting Community Response to Blast Noise*, Technical Report E-17/ADA773690 (CERL, December 1973).

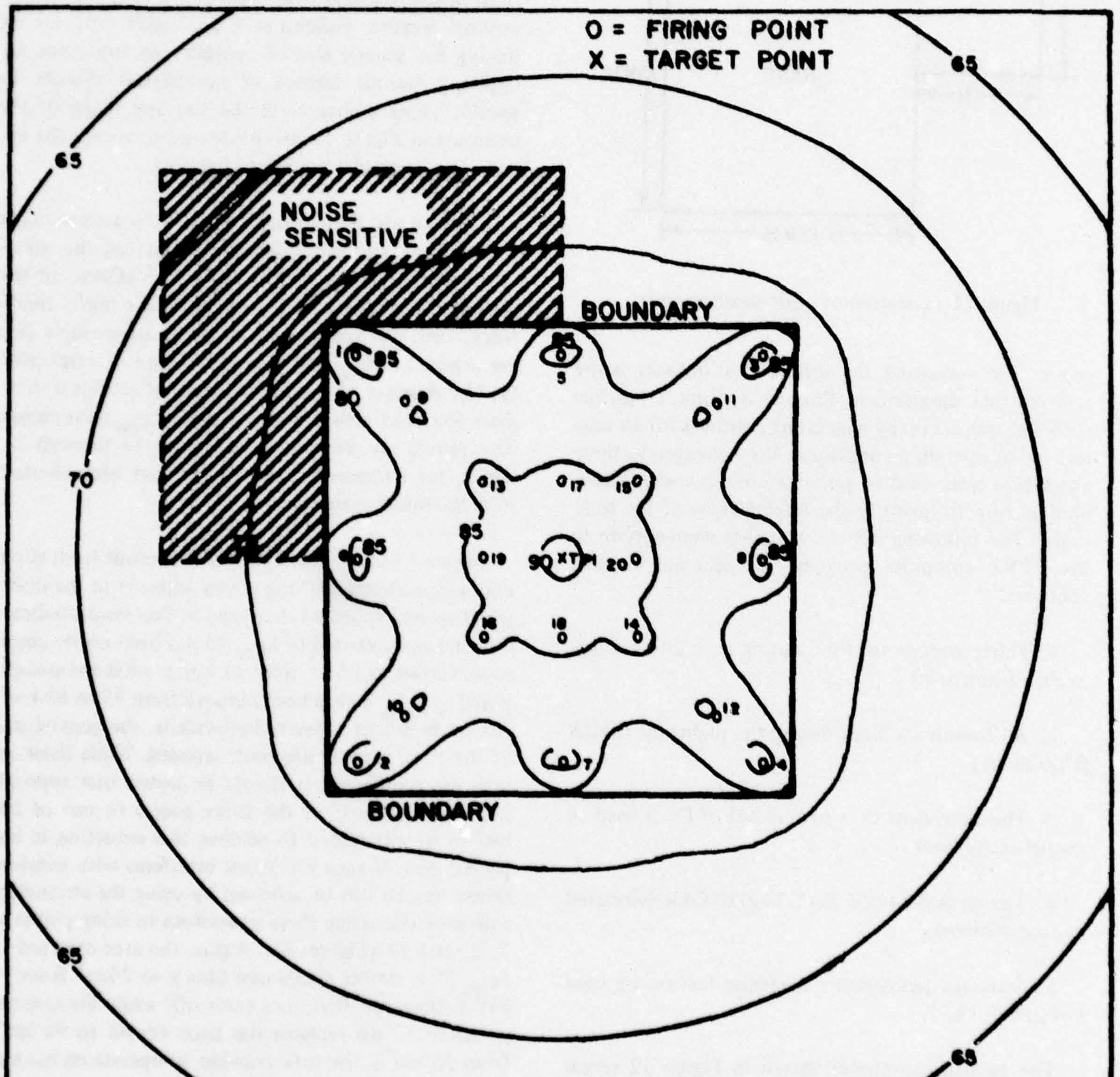


Figure 12. Noise contours of initial conditions (Case II).

Table 4
Summary of Operational Changes (Case II)

Figure	Action Taken at Various Firing Points: Eliminate Operations	Reschedule Night Operations to Day	Relocate Operations: From	To
13	1, 5, 6, 9			
14			1, 5, 6, 9	4, 7, 8, 12
15		1		
16		1, 5, 6, 9		
17		All but firing point No. 4		
18		5, 6	1, 9	4, 12
19	1, 9		5, 6	7, 8
20	1	5, 6, 9		
21	1, 9	Everything else		

Table 5
Effect of Operational Changes (Case II)

L_{Cdn} / Figure	Land Area [km²] Exposed to Various L_{dn} Noise Zones: >60 NS*	>60 Total	>65 NS	>65 Total	>70 NS	>70 Total	>75 NS	>75 Total
12	100		100		95	(937)	31	(531)
13	100		100		82	(680)	1	(298)
14	100		100		93	(846)	2	(373)
15	100		100		96	(804)	21	(335)
16	100		100		85	(692)	3	(304)
17	100	(996)	41	(446)	–	(221)	–	–
18	100		100		90	(771)	1	(319)
19	100		100		89	(758)	5	(311)
20	83	(690)	84	(297)	–	–	–	–
21	87	(696)	12	309	–	(144)	–	–

*Noise-sensitive area

discussed in the previous section, this action is expected to produce even more significant results.

In Figure 15, all nighttime activity at firing point 1 has been rescheduled to daytime hours, with the activity at the other points remaining constant. For a more dramatic effect, Figure 16 shows the results of rescheduling nighttime operations at firing points 1, 5, 6, and 9 to daytime hours. Because of the 10-dB nighttime penalty, this action has almost the same acoustic effect as eliminating the operation. Comparing the cases in Figures 13 and 16 in Table 5 shows almost identical reductions. Finally, in Figure 17, all operations have been rescheduled to daytime hours, except at firing point 4, which is the farthest from the noise-sensitive area. This action eliminates all exposure to levels higher than $L_{C_{dn}}$ 70. Reducing nighttime operations to 10 percent of the total typically achieves all but 2 dB of the potential benefit.

Figures 18 through 21 show different combinations of eliminating, rescheduling, and relocating operations. While eliminating or rescheduling operations has a more significant effect than relocating them, relocation becomes important when interference with the mission prohibits the other two. Even thought the contour area remains relatively constant, relocation can shift the contour away from the noise-sensitive region. Since various factors such as mission, economics, and feasibility may preclude a single approach, a combination of actions is often the most effective procedure.

In Figure 18, operations at firing points 5 and 6 have been rescheduled to daytime hours, while operations at firing points 1 and 9 have been relocated. In Figure 19, operations at firing points 1 and 9 have been eliminated, while operations at firing points 5 and 6 have been relocated. In both cases, the contour shape and resulting reduction in contour are almost identical.

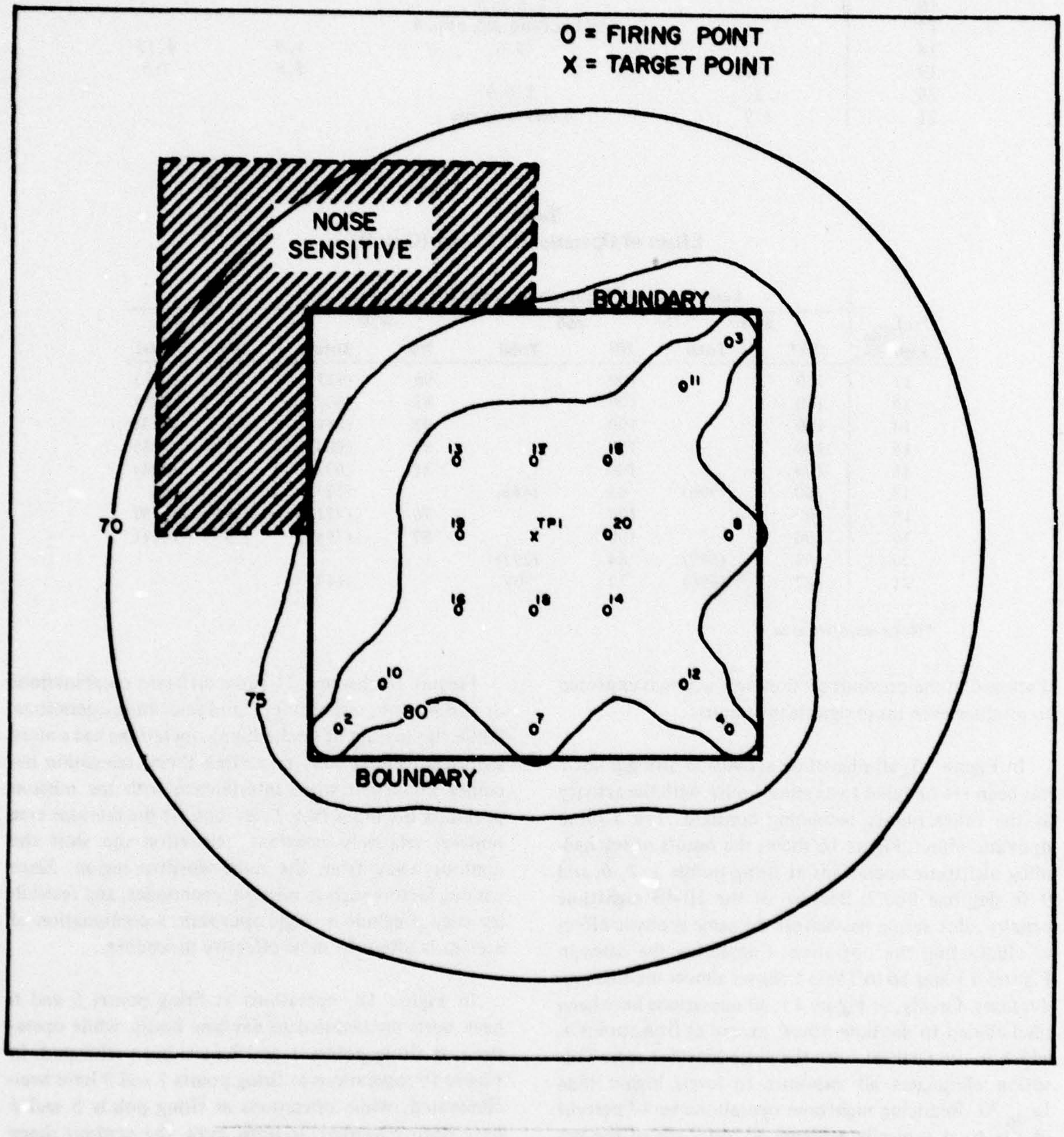


Figure 13. Effects of eliminating operations at points 1, 5, 6, and 9.

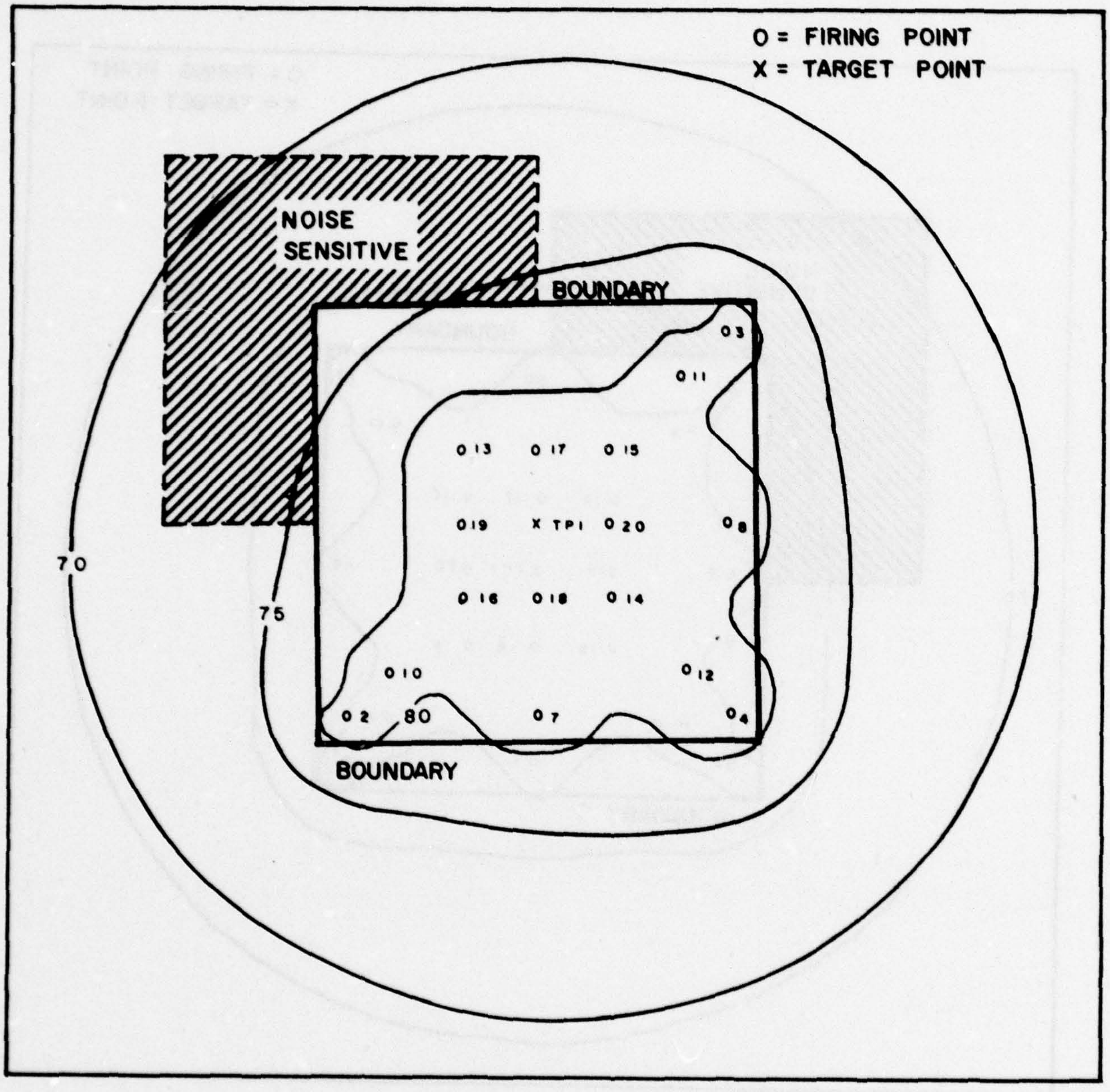


Figure 14. Effects of relocating operations from points 1, 5, 6, and 9 to points 4, 7, 8, and 12.

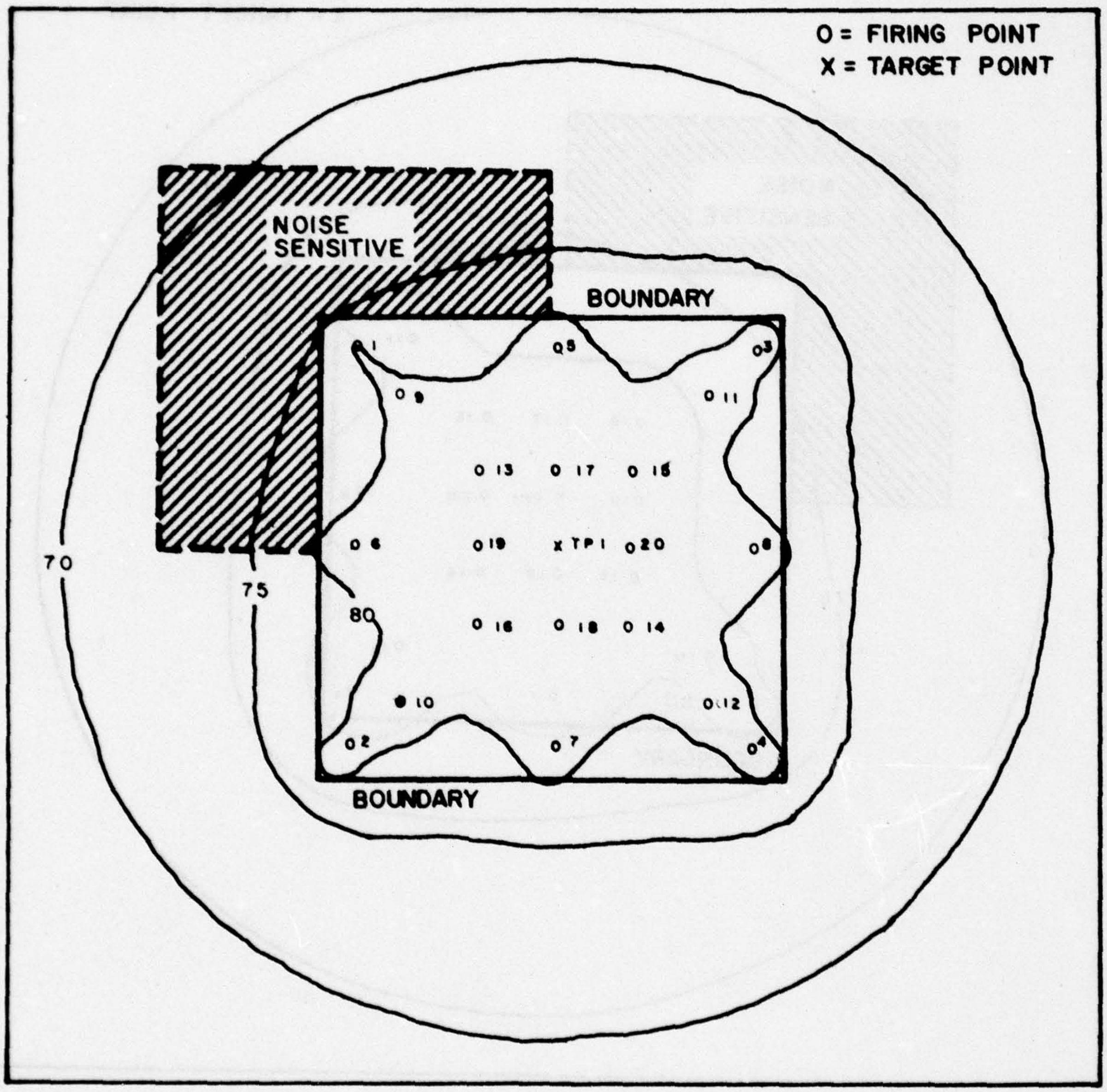


Figure 15. Effects of rescheduling operations at point 1.

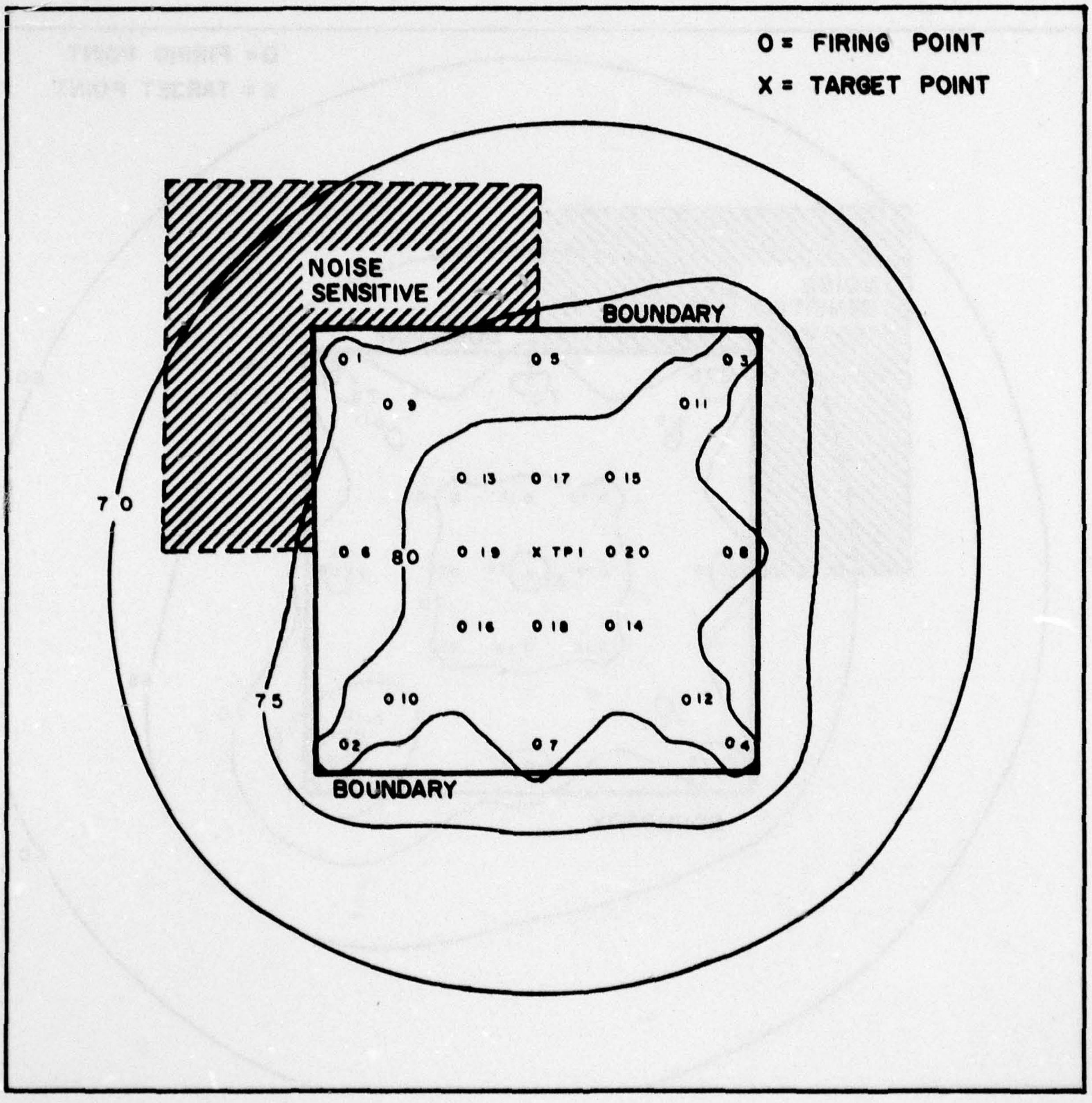


Figure 16. Effects of rescheduling operations at points 1, 5, 6, and 9.

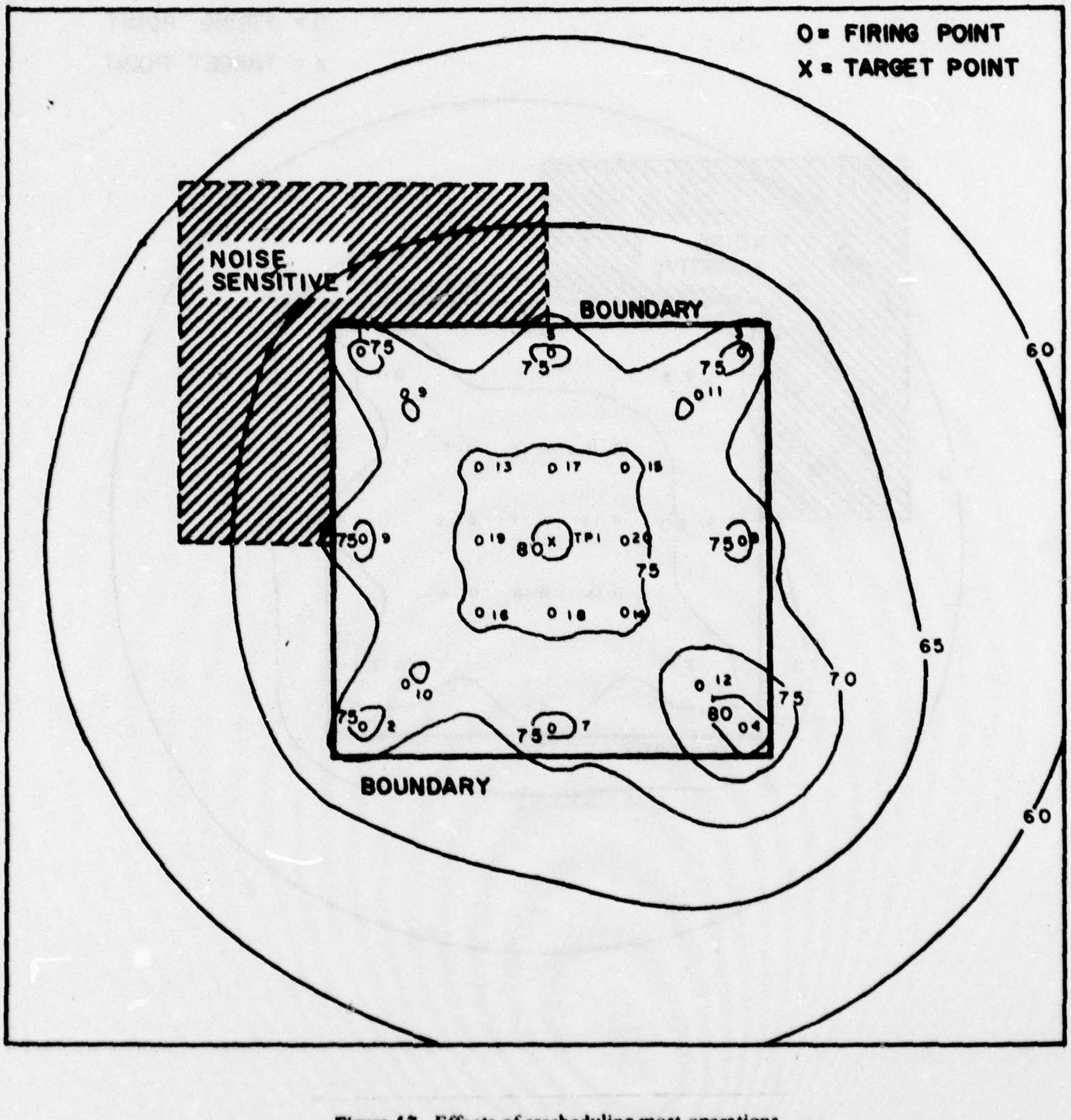


Figure 17. Effects of rescheduling most operations.

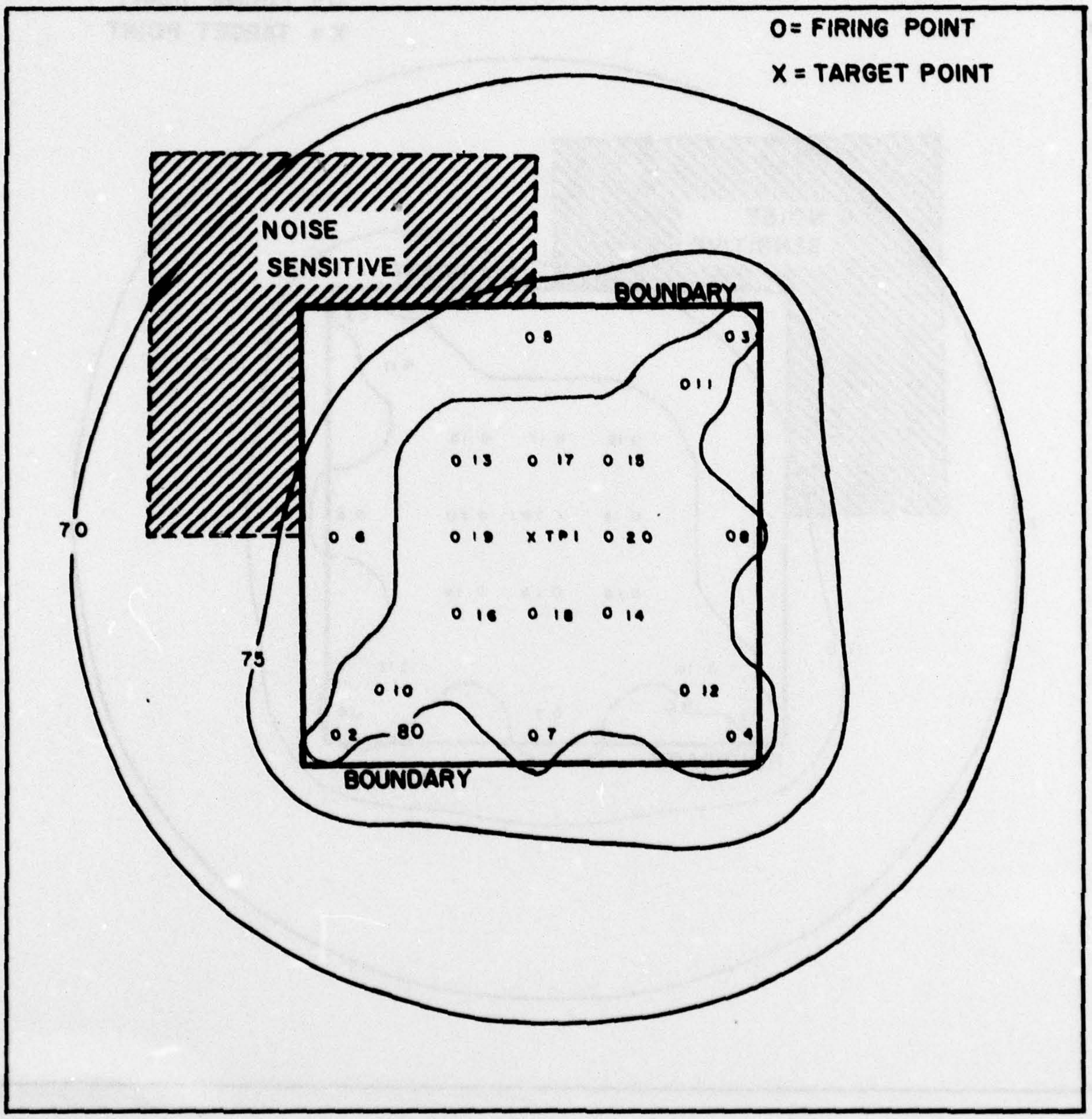


Figure 18. Effects of rescheduling and relocating some operations.

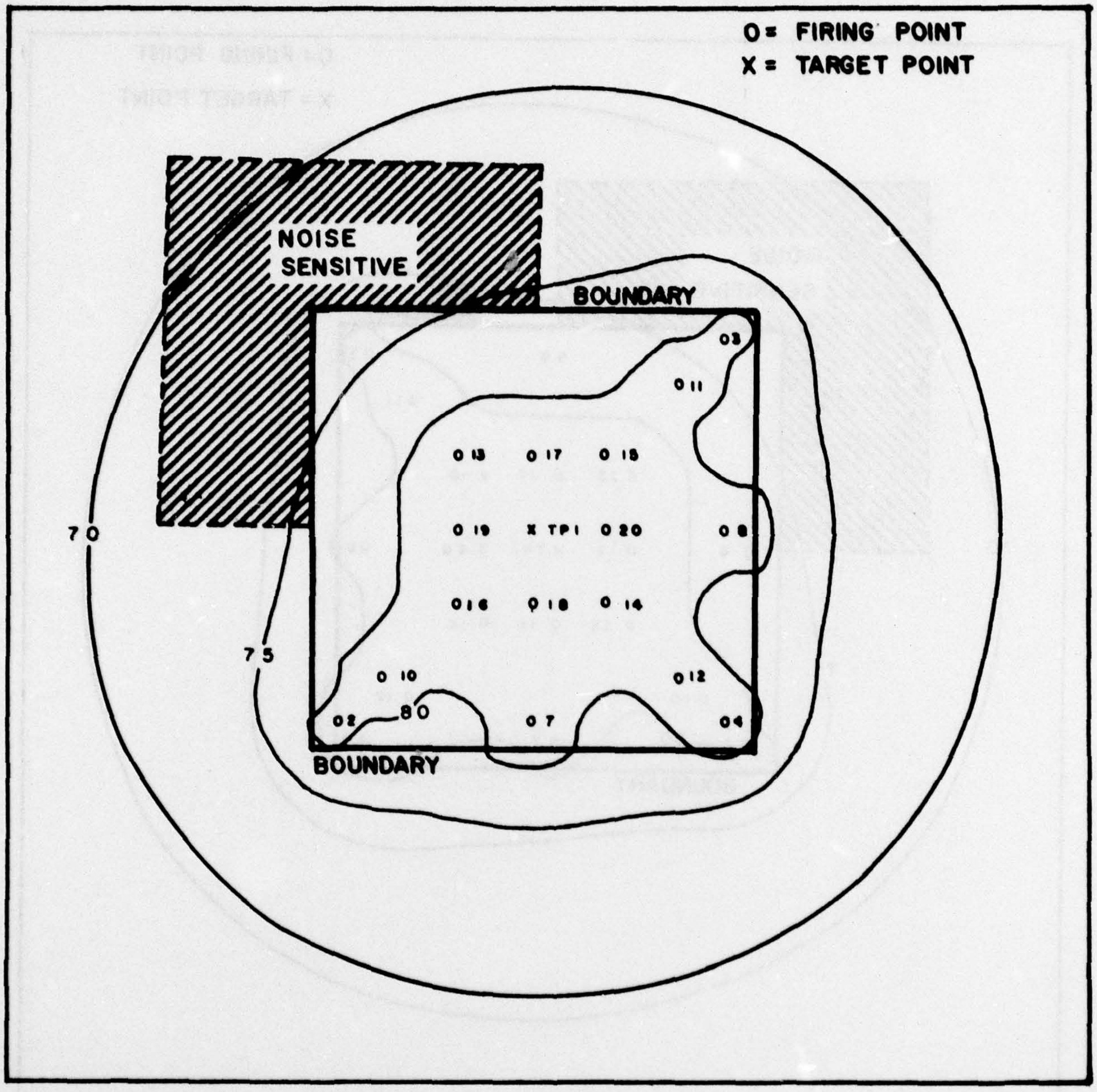


Figure 19. Effects of eliminating some and relocating other operations.

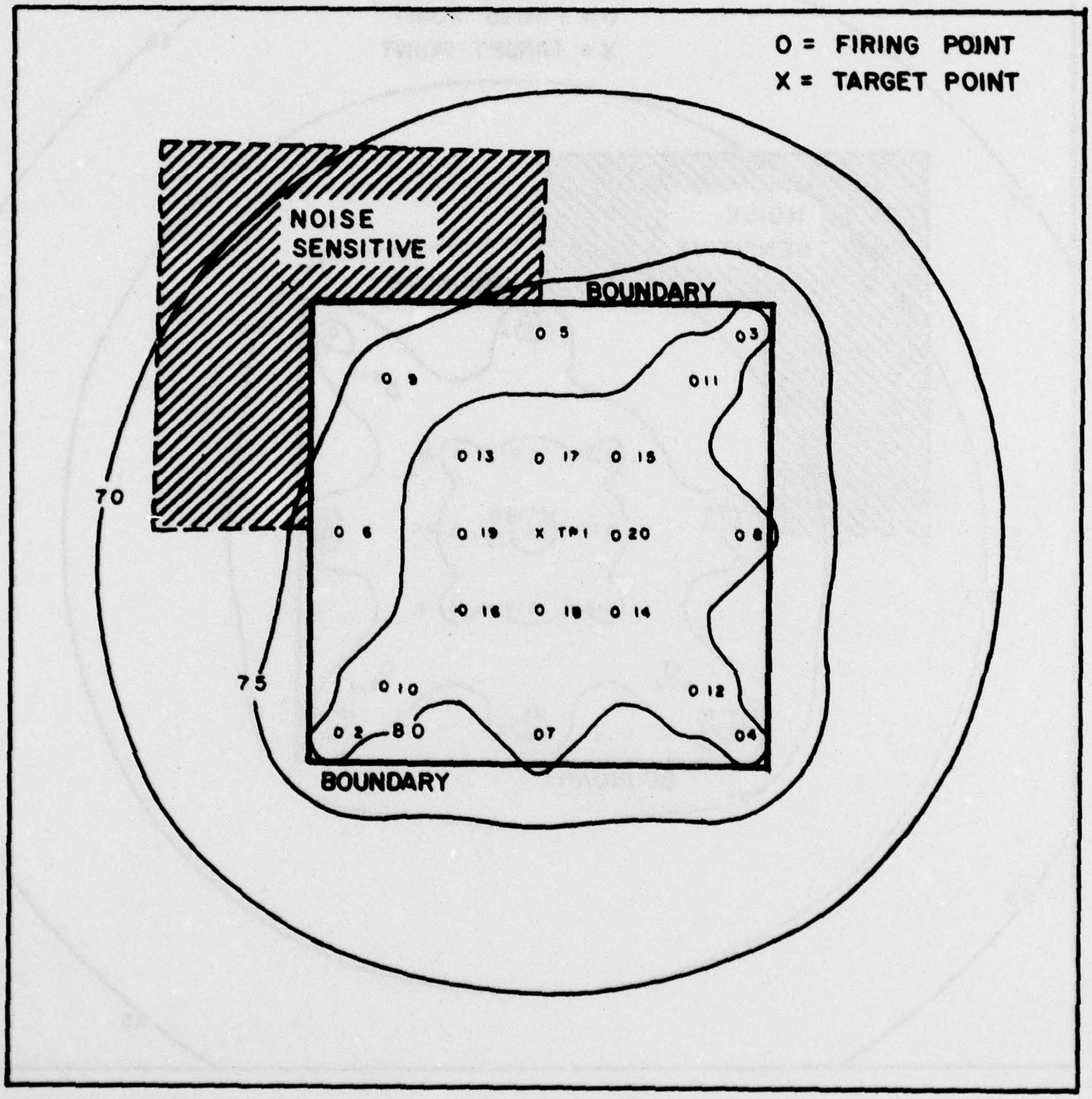


Figure 20. Effects of eliminating one point and rescheduling a few operations.

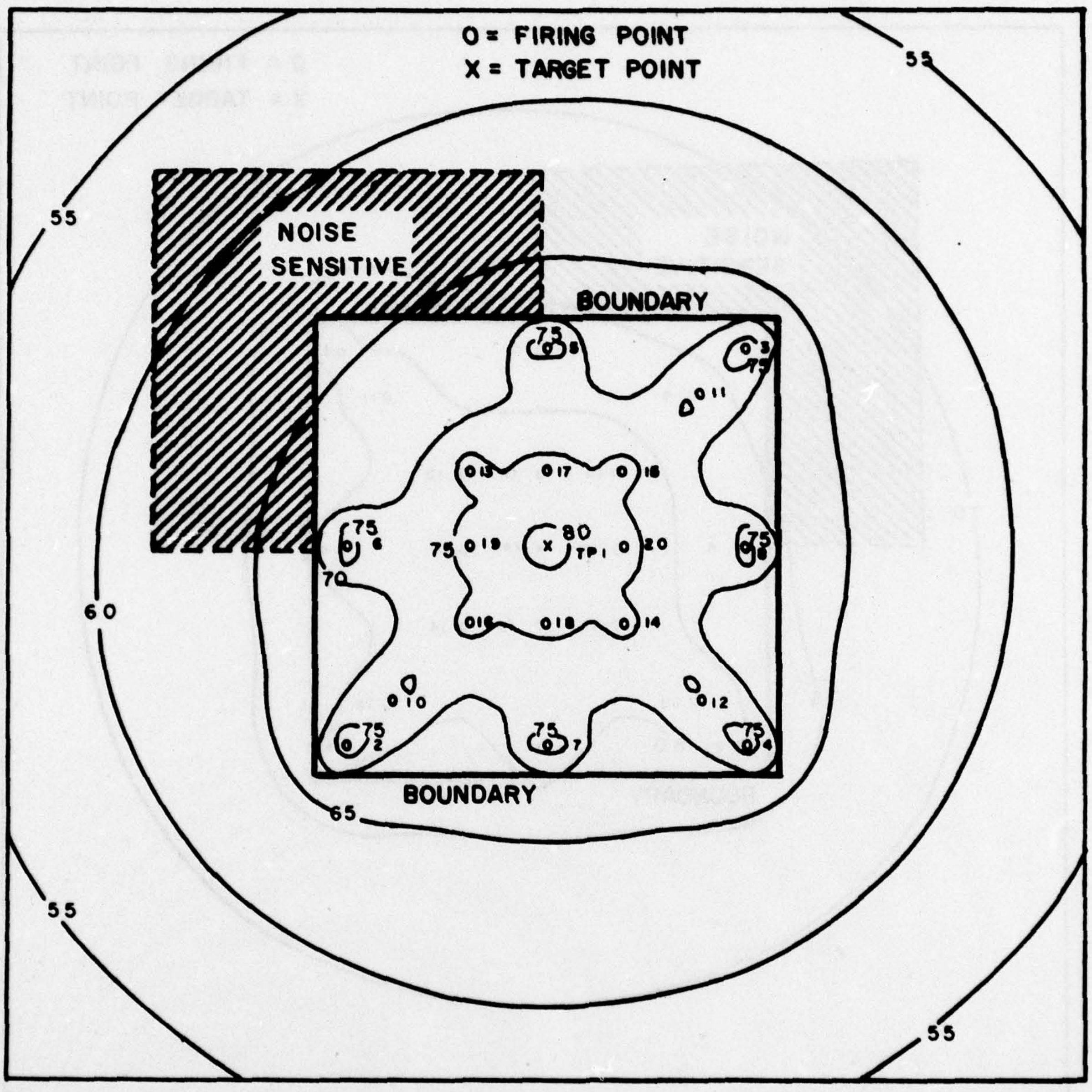


Figure 21. Effects of eliminating two points and rescheduling all other operations.

In Figure 20, operations at firing point 1 have been eliminated, while operations at firing points 5, 6, and 9 have been rescheduled to daytime hours. Finally, in Figure 21, operations at firing points 1 and 9 have been eliminated, and all other operations have been scheduled for the daytime.

Admittedly, these last four cases represent a variety of applications, but Table 5 can give some idea of the trade-offs of the various operational techniques. If the sole objective is to reduce all impact in the noise-sensitive area, the methods in Figures 17, 20, and 21 are applicable. If mission is to be considered, the approach with the minimum interference (see Figure 20), which eliminates operations at only one point and reschedules others at three points, should be used. If the objective is to reduce the area exposed to $L_{C_{dn}}$ 75, then almost all the cases would be applicable.

The optimum method must be determined via a trade-off which considers mission, cost, and feasibility. What may work for one particular set of circumstances may not work for another; each situation must be judged individually.

The purpose of this chapter has been to demonstrate the use of operational changes. In this example, these changes reduced noise levels at a particular site. The effectiveness and constraints of these methods will depend on the individual facility being evaluated.

5 CASE STUDY III – BASE X

While the previous chapters gave some insight into the general use of operational changes as a noise-reduction technique, an actual study will better illustrate their practical application. To accomplish this, Base X has been selected as the setting (Figure 22). There are three major noise-sensitive areas: the towns of Sunrise and Montezuma, which are located on the east border, and the cantonment area within the base boundaries. As a prelude to using actual firing schedules, predictive measures will be used to create the conditions and to obtain the contours. Future studies will attempt to apply operational changes to actual conditions, monitor the decibel reduction, and compute both the cost and effect on mission as well as the dB reduction.

Table 6 summarizes the initial operating conditions. The locations of firing points and target points are shown in Figure 22.

As shown in Table 6, during each 24 hours, a total of 40 rounds are fired at target 5 from both firing points 5 and 8. At each firing point, 24 rounds are fired during the day, and 16 are fired at night. The equivalent of 5-lb (2.3-kg) charges of C4 are used to propel and detonate the warhead. Standard temperature inversions are used (ground, 74.2 percent; 1 to 500 m, 08.6 percent; 1 to 3000 m, 18.7 percent). The schedules at the other points are summarized similarly.

Noise contours for these initial conditions are illustrated in Figure 23 and summarized in Table 7. All three noise-sensitive areas are exposed to levels of more than $L_{C_{dn}}$ 70. In addition, approximately 75 percent of Sunrise and 40 percent of Montezuma are exposed to levels of more than $L_{C_{dn}}$ 75. The objective, therefore, will be to reduce the exposure in Montezuma, Sunrise, and the cantonment area. This will involve both of the previously discussed concepts—decreasing the general size of the contours and reducing the noise levels at a particular site. Tables 8 and 9 summarize the operational changes attempted to achieve these goals, and the resulting effects, respectively. Each step is cumulative.

The first change is an attempt to reduce the noise levels at Sunrise. Here, the night operations at firing

Table 6
Original Firing Conditions (Base X)

Firing Points	Target Points	Number of 5 lb (2.3 kg) Rounds Fired Each 24 Hours: Day (0700-2200)	Night (2200-0700)
5, 8	5	24	16
7, 10, 14, 18	7	18	12
27, 28, 30	7	18	12
40, 46, 50, 53	13	18	12
58, 66, 73, 78	22	12	8
79	22	12	8

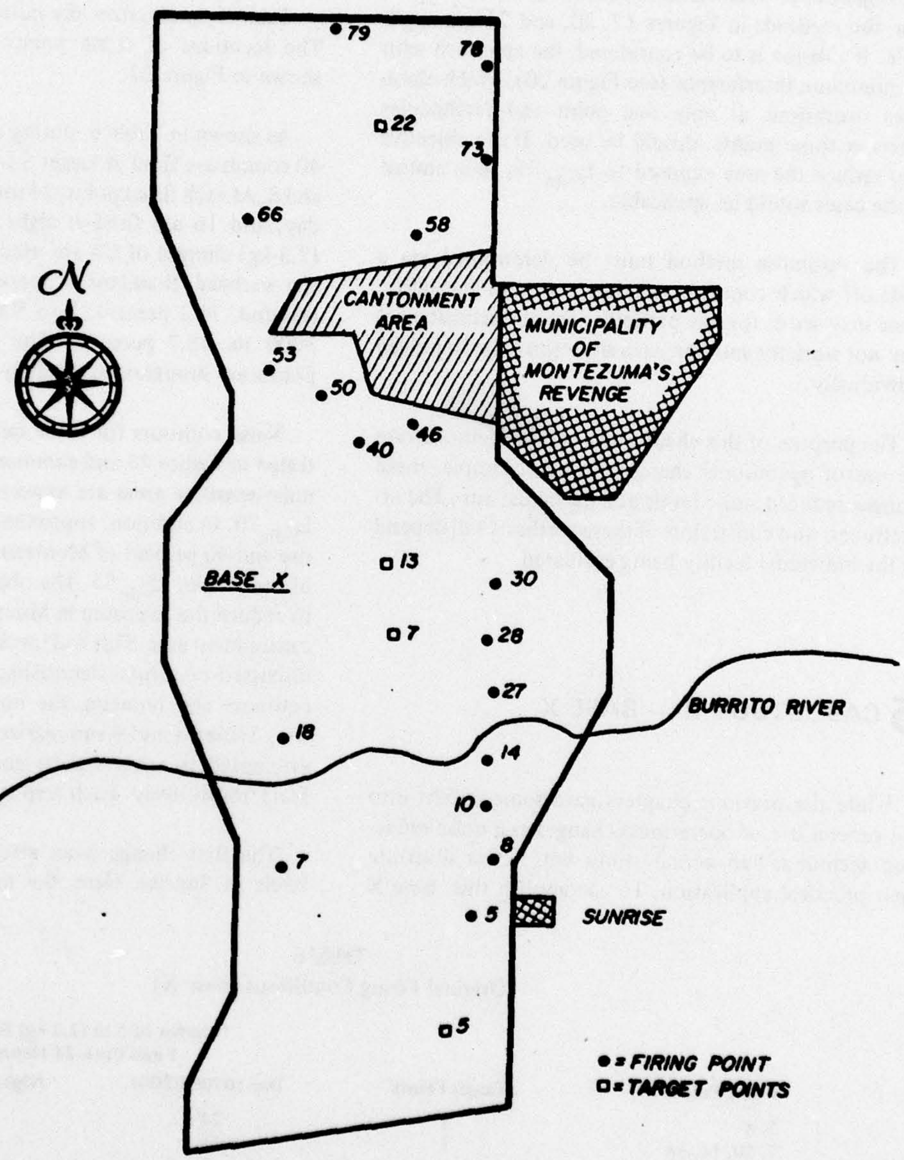


Figure 22. Firing and target points of Base X.

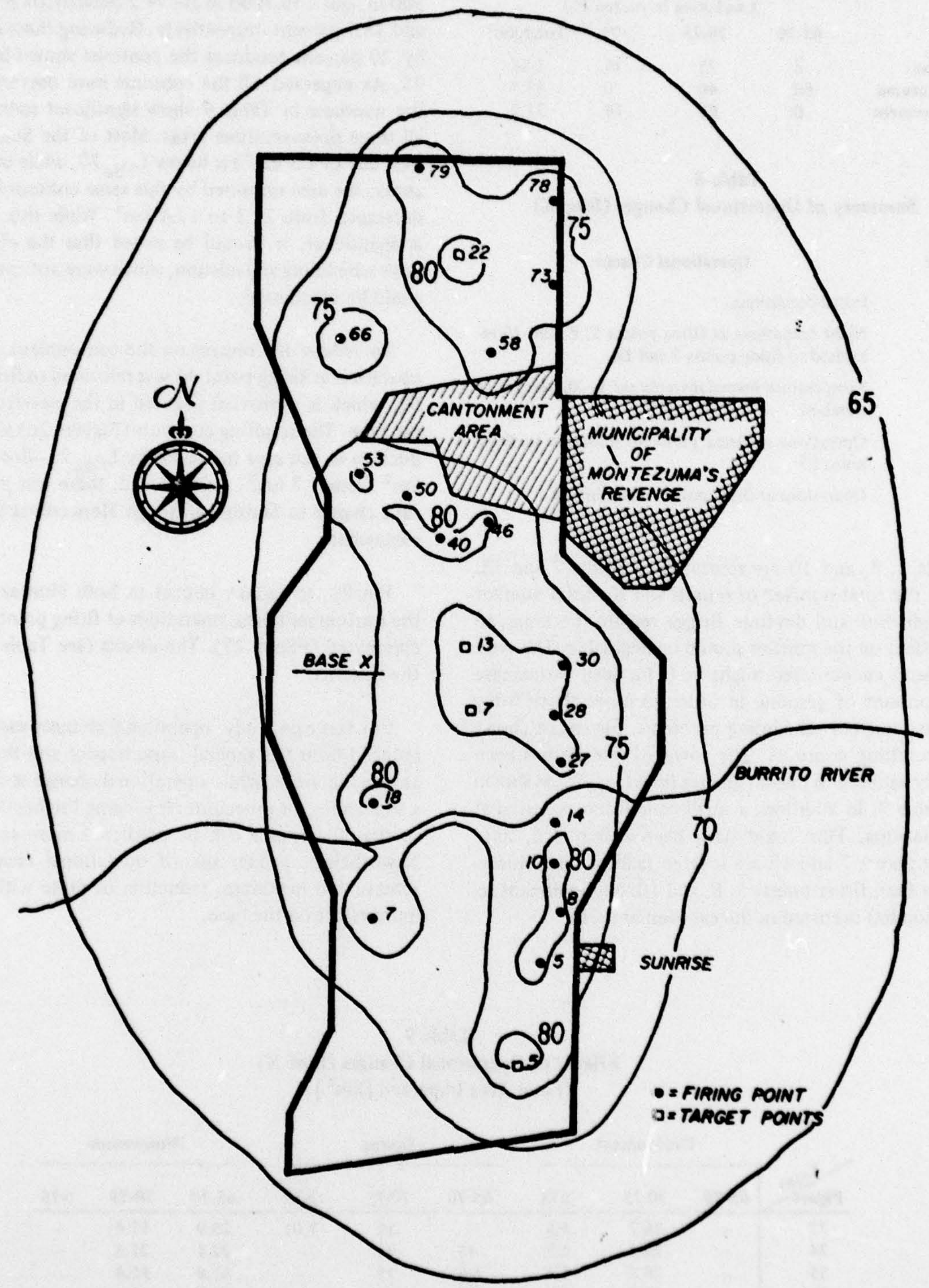


Figure 23. Noise contours for original conditions.

Table 7
Noise Impact from Initial Conditions (Base X)

	Land Area Impacted (%)			
$L_{C_{dn}}$	65-70	70-75	>75	Total km²
Sunrise	0	25	75	1.35
Montezuma	60	40	0	43.3
Cantonment	0	86	14	31.2

Table 8
Summary of Operational Changes (Base X)

Figure	Operational Change
23	Initial conditions
24	Night operations at firing points 5, 8, and 10 relocated to firing points 7 and 18
25	Temperature inversions reduced to 80 percent of standard
26	Operations at firing point 46 relocated to firing point 53
27	Operations at firing point 73 eliminated

points 5, 8, and 10 are relocated to points 7 and 18. Both the total number of rounds and the total number of nighttime and daytime firings remain the same, so the effect on the mission should be negligible. The only problems encountered might be (1) a need to increase the amount of gasoline in order to move those firing points, and (2) scheduling problems. Figure 24 shows the resulting contours. The town of Sunrise has been totally relieved of impact greater than $L_{C_{dn}}$ 75, as shown in Table 9. In addition, a small benefit has occurred at Montezuma. This could have been anticipated, since firing points 7 and 18 are located farther from Montezuma than firing points 5, 8, and 10. No significant reduction has occurred in the cantonment area.

The next step was to try to use more optimum weather conditions as well as rescheduling. Under standard conditions, the inversions at ground level, 1 to 500 m, and 1 to 3000 m are 74.2 percent, 08.6 percent, and 18.7 percent, respectively. Reducing these numbers by 20 percent produces the contours shown in Figure 25. As expected, all the contours have decreased, and the numbers in Table 9 show significant reduction in all three noise-sensitive areas. Most of the Sunrise area (0.9 out of 1.3 km²) is below $L_{C_{dn}}$ 70, while in Montezuma, the area impacted by this same contour has been decreased from 21.3 to 12.4 km². While this decrease is significant, it should be noted that the effects on both scheduling and mission, which were not considered, could be substantial.

To reduce the impact on the cantonment area, the operation at firing point 46 was relocated to firing point 53, which is somewhat isolated in the western part of the base. The resulting contours (Figures 26) show a reduction in the area impacted by $L_{C_{dn}}$ 75 – down to 0.4 km² from 1.7 km². As expected, there was no significant change in Sunrise, although Montezuma benefited somewhat.

Finally, to reduce impact in both Montezuma and the cantonment area, operations at firing point 73 were eliminated (Figure 27). The results (see Table 9) show the benefits.

For this case study, operational changes successfully reduced both the general noise impact and the impact at specific areas. While operational change is currently a trial and error procedure, it is being further developed so that the results can be predicted more accurately. Nevertheless, proper use of operational changes can achieve the maximum reduction of noise with a minimum effect on the base.

Table 9
Effects of Operational Changes (Base X)
(Land Area Impacted [km²])

	Cantonment			Sunrise			Montezuma		
Figure \ $L_{C_{dn}}$	65-70	70-75	>75	65-70	70-75	>75	65-70	70-75	>75
23	–	26.7	4.5	–	.34	1.01	25.9	17.4	–
24	–	26.3	4.9	.45	.90	–	22.1	21.3	–
25	–	29.5	1.7	.90	.45	–	31.0	12.4	–
26	–	30.8	0.4	.90	.45	–	34.3	9.1	–
27	0.8	29.7	0.7	1.01	.34	–	36.3	7.0	–

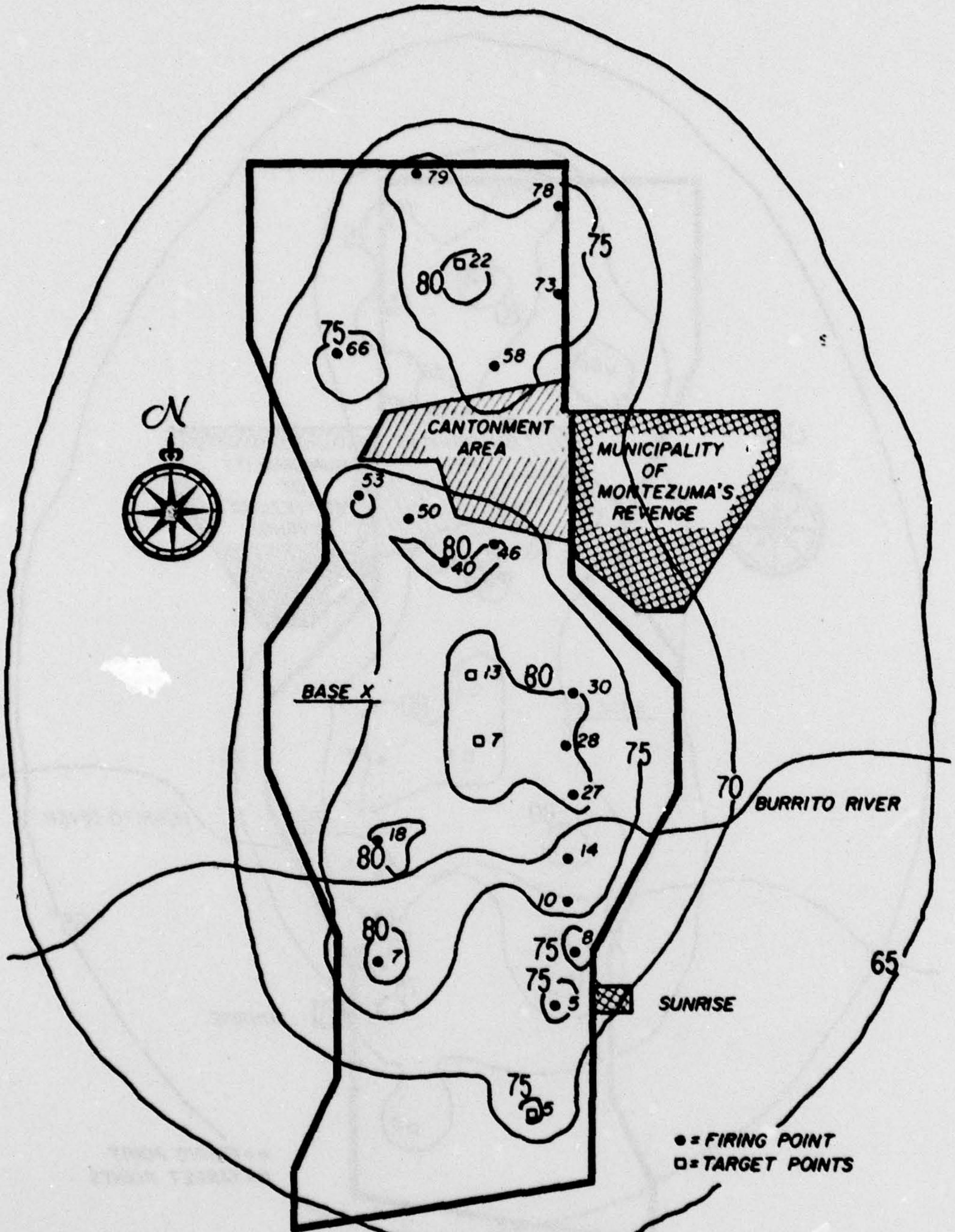


Figure 24. Effects of relocating operations from points 5, 8, and 10.

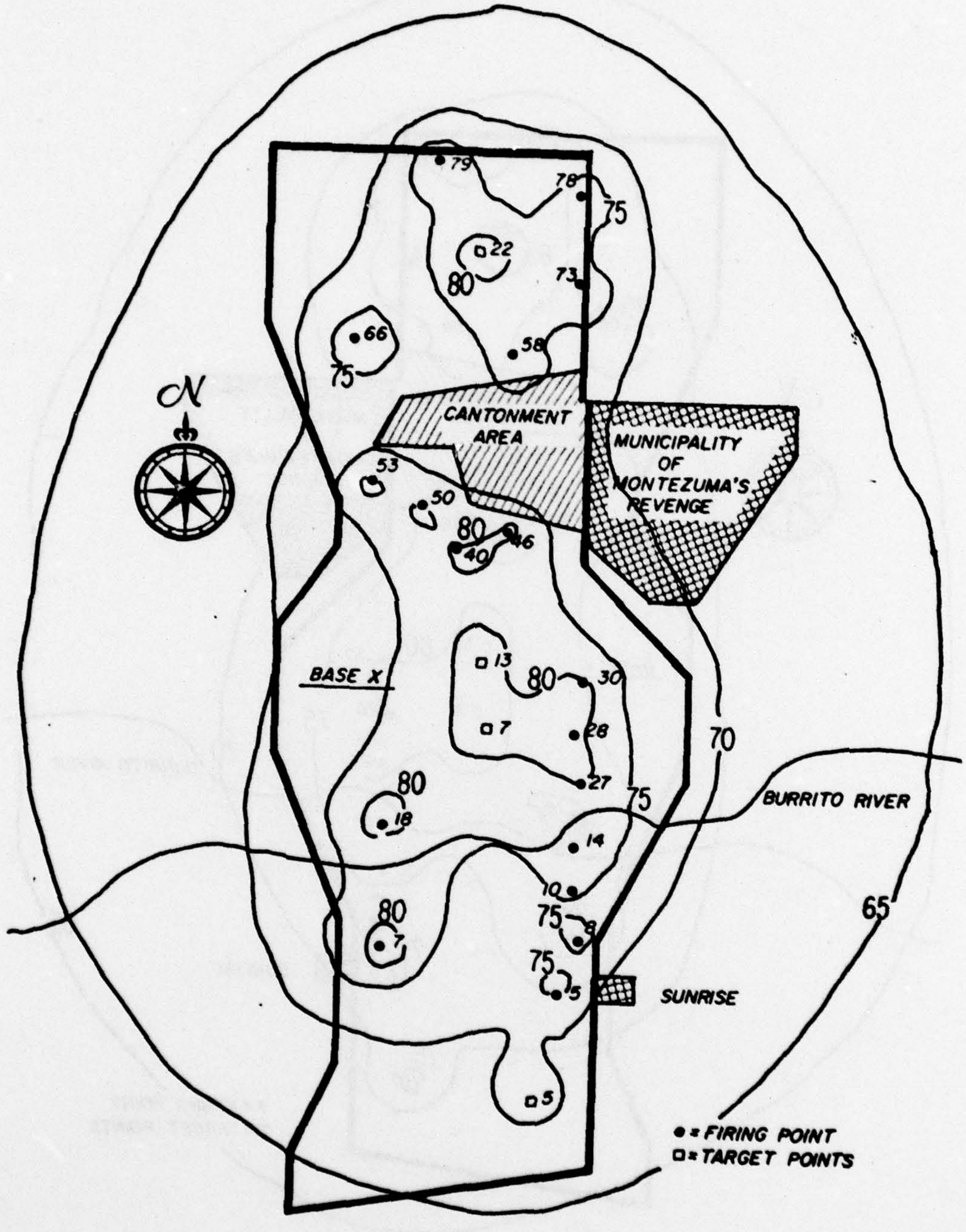


Figure 25. Effects of firing during fewer inversions.

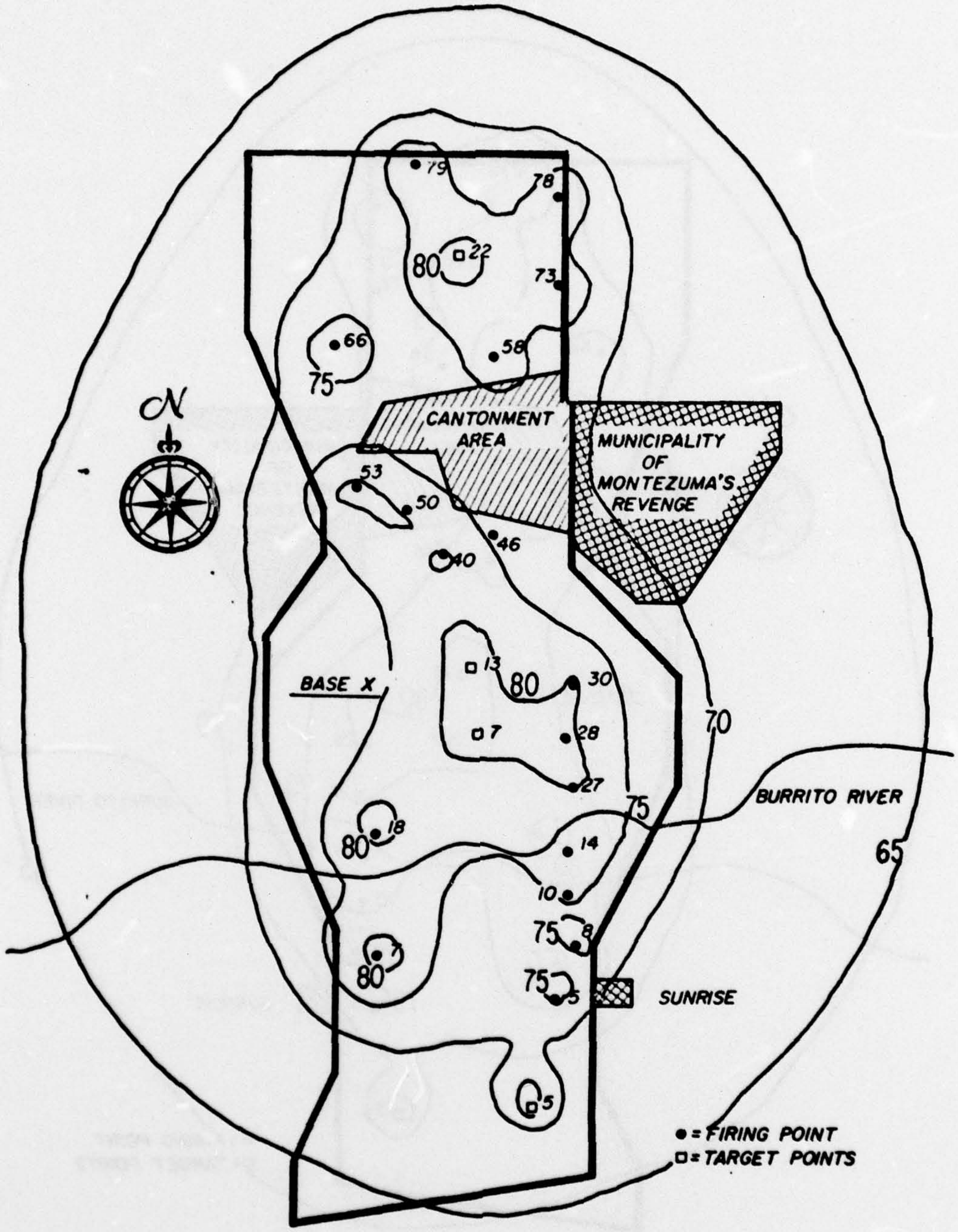


Figure 26. Effects of relocating operations from point 46.

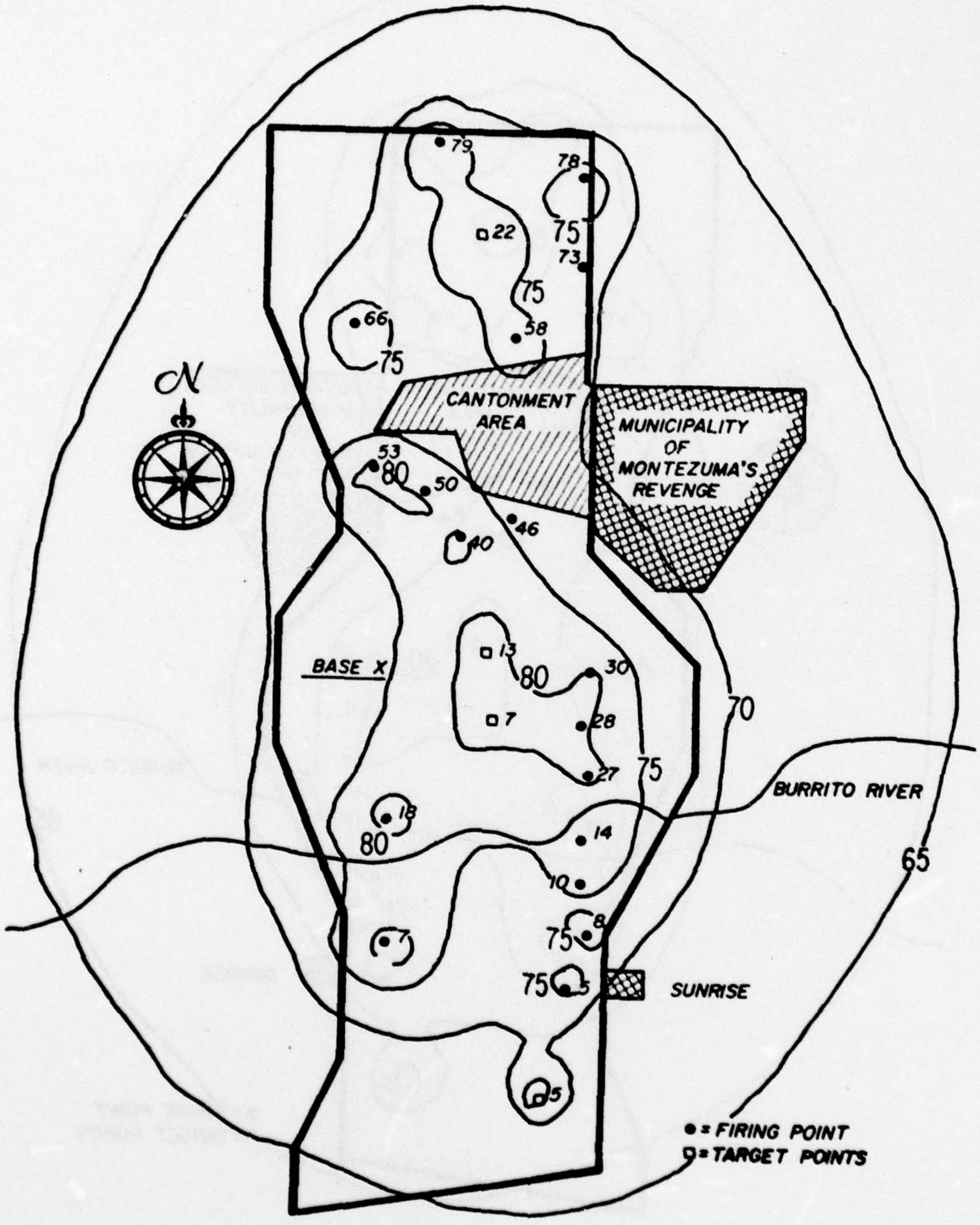


Figure 27. Effects of eliminating point 73.

6 CONCLUSIONS

The following conclusions are based on this research:

1. Relocation, rescheduling, and use of optimum weather conditions can reduce the level of noise perceived by the receiver.

2. Applying operational changes to hypothetical blast conditions and generating noise contours and evaluating their areas enabled quantitative evaluations of the effectiveness of each technique.

3. Mitigative methods are site-specific, and the decision to use a particular method must be based on its effects on mission, cost-effectiveness, decibel reduction, and benefits to a specific facility.